UNITED STATES DEPARTMENT OF AGRICULTURE

# REPORT ON THE AGRICULTURAL EXPERIMENT STATIONS, 1927



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## OFFICE OF EXPERIMENT STATIONS

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E. W. ALLEN, W. H. BEAL, W. H. EVANS, J. I. SCHULTE, R. W. TRULLINGER

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Washington, D. C. October 31, 1928

# REPORT ON THE AGRICULTURAL EXPERIMENT STATIONS, 1927

By E. W. Allen, W. H. Beal, and J. I. Schulte[1]

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## INTRODUCTION

The year 1926–27 was one of substantial progress in the development of the work of the experiment stations. With increasing funds the stations were able to strengthen their personnel, improve their equipment and facilities for work, and broaden their research programs. Along with the broadening of the field of inquiry, there was a growing appreciation of the need of improved methods of research and of more critical analysis and interpretation of the data obtained.

The following report, made in compliance with law, gives a review of the progress, problems, and outlook of the stations as shown by a study of their work during the year, as well as a record of their income and expenditures, improvements, and publications.

## PROGRESS AND TRENDS

### PREPARATION OF WORKERS

Men, methods, and money are the prime essentials for growth of investigation, in the order named; but they need to be combined to assure success. The assignment of money is merely the evidence of things hoped for, but alone assures nothing, while methods without the vision and insight and initiative of trained investigators may mean mechanical routine without research. Hence the worker is fundamental; the presiding genius determines the grade of the effort and the size and reliability of the contribution which results from it.

But it takes time to train workers, especially to a point for independent investigation. It means the inculcation of standards and motives quite as much as acquaintance with what is in the books. The spirit of research and the attitude of inquiry are an essential part of the equipment, and these are just as applicable where the ends are practical as where they deal with more theoretical considerations. It is mainly in connection with advanced study that the student forms his conceptions and impressions of what research is and the difference between research and a good thing, the distinction between a scientific fact and a bit of information. It is here that he acquires the spirit of inquiry which leads him from a statement of facts to the question, What of it?

[1] With the collaboration of other members of the office staff.



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So the kind of graduate work matters very much in the preparation for research. Its value depends on what the student gets out of it, not alone in principles, theories, and facts, but in scientific discipline, inspiration, and the sense of values; not alone in enthusiasm, but in ability for well-directed energy.

To borrow from another, interest in a subject alone does not assure accomplishment; that interest must be driven by intelligence and by an understanding of the way to advance it. But even an intelligent person can not make his best contribution to existing knowledge unless he has the necessary experience and information and has developed skill in using them. These are a product of severe training.

Some one has defined the requirements for research as—

> intelligent students in whom sustained interest and wonder have been aroused; experiences of their own which furnish an effective basis for thinking; a mastery of the already organized knowledge in the field in question; and disciplined skill in sound processes of inquiry.

This is a very pregnant statement, applicable in principle to various grades of inquiry. To rely on those who lack these qualifications is to increase the speculative feature of the research investment, which is large at best, with the danger of extravagance.

Belief is influenced by the wish to believe. The open mind needs to be checked by scepticism and impartial criticism. The trained investigator is a sceptic in that he admits nothing without proof. He seeks to account for facts and phenomena before accepting them. He is not only the observer and the student but the questioner, the doubter, until evidence compels belief, cautious and exacting and schooled in his thinking.

As research institutions the stations are not the amateurs they once were. They are "standing on the shoulders of the past"—of men who have done the pioneering and marked out some of the trails. More is expected of their workers, and justly so. Since the standard has risen, it is well that both selection and elimination are taking place in the staff of investigators. This warrants placing a premium on special preparation and establishing it as one of the requirements of advancement.

Of appointees since the Purnell Act went into effect, nearly 70 per cent held advanced degrees, 25 per cent of them having the doctor's degree, thus indicating a trend toward more highly trained workers, although perhaps not to the extent that might be expected or desired.

Manifestly, too much emphasis should not be placed on academic degrees. They do not necessarily stand for accomplishment or ability in the field of productive research, and persons having them frequently are outdistanced by those who have not attained them. Such degrees of themselves merely express advantages which have been enjoyed for systematic advanced study leading to the completion of certain stated requirements. If this has been of the right type and profited in, it is an asset which may be reflected in better preparation for research and enlarged opportunity for growth.

There are some noticeable differences among the applied subjects with respect to the academic degrees of their personnel. In this respect animal industry, for example (including animal husbandry, poultry, and dairying), is considerably below similar applied subjects, like agronomy and horticulture. No less than 42 per cent of the animal-industry departments are headed by persons who have not advanced beyond the bachelor's degree, which may seem a rather large proportion for department heads in research institutions. In the case of agronomy and horticulture it is only half as large, 22 and 21 per cent, respectively. The percentage of department heads in animal industry having doctor's degrees (including five veterinarians) is only 14, compared with 32 in agronomy and 24 per cent in horticulture.

Less than half the animal-industry staffs (46 per cent) include anyone who has gone beyond the master's degree, while four stations list no one in animal husbandry above the bachelor's degree, and six stations none in the case of dairying. In the animal-industry departments combined a total of 52 persons have gone beyond the master's degree, representing 22 of the stations, while for agronomy the number is 81 at 31 stations, and for horticulture 64 at 24 stations.

In other words, the workers with the advanced degrees are considerably more numerous and more widely distributed in agronomy and horticulture than they are for the animal industries. It is gratifying to note, however, that the trend, as indicated by the new appointees during the past two years, is more closely in line with these other applied subjects.

### NATURE OF RESEARCH

The attempt to advance information and bring about improvements in agriculture recognizes various grades of effort. These range all the way from relatively simple tests and observations, for the most part routine in nature, to the most advanced types of original research.

Isolated experiments designed to make comparisons between different materials and processes long constituted a large part of the work of the stations. They had an important place and gave results which were useful as far as they went. But as investigation advanced and problems were seen more clearly such experiments naturally became subordinated to a dominating idea and were made parts of more systematic inquiries in the working out of a problem. With a clearer concept of problems and the setting up of more concrete objectives, it has become evident that adherence to routine will not lead very far but gives a product of quite limited application.

In the growth of discrimination between various types of inquiry the term "research" came to have a quite distinctive meaning as typifying the more advanced and fundamental character of investigation. Latterly, however, the word is coming to be used loosely and, to some extent, is in danger of losing some of its former significance. This may influence the thinking and the standards of those engaged in it, as well as the general public.

The use of "research" in a generic sense in popular writings has tended to create confusion in the public mind, and the advertising value of the work from a commercial standpoint has accentuated this liberty of use. The example of large industries which have established extensive research departments to assist in developing their processes has been followed by smaller establishments which give prominence to so-called research laboratories designed and conducted merely for simple testing operations. A recent writer, in referring to the common perversion of the word, declares that research has become "a term used not infrequently without any adequate appreciation of its fundamental implications."

When the Adams Act was passed in response to the recognized necessity for larger attention to fundamental investigation, it defined the type of activity to be carried on under it as "conducting original researches or experiments." Taken in connection with its history, it was recognized that an advanced type of fundamental inquiry was implied, and this view was generally accepted. The Adams Act went a long way toward clarifying distinctions and setting up standards for the more systematic and thoroughgoing type of investigation. It has had a powerful influence for the encouragement of such advanced research, and the results have demonstrated that the latter may be of great practical service to agriculture. It is fortunate that there has been such a fund, so safeguarded that it might be applied continuously and without undue pressure for immediate practical results to projects requiring the most advanced scientific methods and the highest technical skill.

The Purnell Act very properly was not restricted in the same terms as the Adams Act, for different grades of work are needed, especially in some of the newer lines. It was made clear, however, that an effective type of inquiry was implied, such as would be understood by the terms "investigations," "experiments," and "scientific researches," used in the act. Evidently these terms were used advisedly and intended to carry their usual meaning, having due regard to the purposes of the act.

Perhaps it may be argued that all the station activity should be of such grade that "research" will properly describe it, but no one can seriously expect this at the present stage, either in theory or practice. To class under that caption simple tests and trials, short-range experiments of the conventional order, service and reconnoissances, enumerations, and the gathering of other general information, however essential, incurs the possibility of being grouped with those who use the term "without any adequate appreciation of its fundamental implications."

Research, as commonly understood, means more than accumulating data or compiling information; it means gathering data for a particular purpose guided by ability to discern the kind of data necessary, to weigh their adequacy, and to interpret them rather than merely to summarize them. Research is not only an advanced type of inquiry but a mature effort, dominated by an attitude of intellectual curiosity. It is this mental attitude that impels the investigator to be exacting of himself, to search beyond the empirical information in the attempt to understand obvious facts and occurrences. The underdevelopment of won-

der and imagination, of desire to go beyond the superficial and the obvious, retards investigation in certain lines and makes workers satisfied to follow a set formula of conventions. Such limitations give comparative results good only for the time and place, but no substantial general fact or understanding of relationship between the effect and the cause.

There is need for discrimination in the use of "research," and there is need for upholding the standards it implies under the Adams Act. Some evidence is apparent of a disposition to let down these standards and requirements, to engage in projects which do not look very deep and are not designed to be very thorough or constructive in a fundamental sense. This may possibly be a result of a too free use of the term the act formerly stood for.

The stations now have large amounts of money for less recondite and fundamental types of work. It would seem advisable for every station to carry on original research, at least to the extent that the Adams fund provides, and make its contribution to knowledge on the frontiers of agricultural science. In enlarging the range of the station work it ought not to be forgotten that the aim is not only results which have direct application but the things that are permanent and give understanding.

### SOME NEW DEVELOPMENTS

The problems met with in agriculture are recognized as very complex and hence difficult of solution. They have proved elusive until they could be analyzed and their real nature and content determined. This often has delayed getting understandable answers to commonplace questions which seemed on the surface to be fairly simple.

One evidence of advance in research is the perfection of means and facilities by which the essential factors can be separated and studied more intensively. This involves provision for bringing them under control and measuring their effect alone and in combination. It enables not only more conclusive studies regarding the various environmental features but the growth requirements of plants and animals, the conditions favorable as found in practice, the cause of unfavorable response, and the like.

Steady advance in what may be termed the technic of agricultural research has been taking place for several years, especially in the past decade. Recent years have supplied numerous examples of it. These mark progress in acquiring a deeper insight into the nature of questions under study and into what is necessary for their solution. The more penetrating point of view and the means devised for pursuing it in further inquiry mark departures from the conventional which are characteristic of real research.

A notable step a few years ago was the perfection of apparatus for control of temperature and humidity of air and soil in studying the relations of crops to disease organisms, and the conditions which enable the effects of the latter to be more largely avoided. This technic has been applied to increasing extent, and has been extended to determining the temperature relations of plants, with appliances for ascertaining, for example, the minimum temperatures which different varieties of winter wheat, alfalfa, grasses, etc., can survive, and also the highest temperature other crops can stand without injury. A cold-temperature laboratory constructed at one of the stations contains four rooms capable of being held at temperatures of 32°, 14°, —4°, and —58° F., respectively, each under separate control, which will provide unusual facilities for the study of winter hardiness and cold resistance of plants. Again, greenhouses have been so constructed as to provide different temperatures for investigating the longevity and behavior of certain plant-disease organisms, and for facilitating experiments on the influence of temperature on germination, growth, and development of plants.

Since the factor of light, its intensity and duration, has become more clearly evident, a system has been devised at one of the stations which has enabled securing a further insight into this factor and temperature in plant growth. Using constant temperature and strength of illumination, practical quantitative response as measured by the dry matter produced in the growing plant has been secured, in proportion to duration of lighting.

An interesting refinement in the study of crop nutrition has been worked out in which dependence of the crop on the soil and its uncertainties is eliminated. By means of solution cultures the unit of growth for each of the fertilizing constituents is determined, the minimum requirement of the crop, which is con-

stant for the variety, being compared with the amount absorbed by the plant, which is excessive under usual conditions of growth. The relation of the growing period of varieties to the utilization of the materials taken up, the possibility of storing up materials for later stages of growth, the effect on quality, etc., have developed some new facts regarding adaptation and fertilization.

The reaction of the soil has shown a new relationship in its effect on the growth of organisms causing certain plant diseases; and the hydrogen-ion concentration, a measure of acidity or alkalinity of materials, has found widening applications, as in explaining resistance to organisms, the relation of fruit juices to jellying, and otherwise. The genetic effect of X-rays on corn has opened interesting possibilities, and these rays have been employed successfully in studying plant fibers as to their molecular arrangement and the effects of treatment. Thus new tools are brought into use which enlarge the range of vision of the investigator in his search.

The respiration calorimeter for studies in animal nutrition used to be rare. Originally built for experiments with man and small animals, it has been enlarged, adapted, and improved so that it is available in many places for studies with domestic animals and their response to food and other factors. The discovery of the importance of certain mineral constituents and their specific effects, as well as those of their deficiencies, has thrown a new light on these hitherto underestimated constituents; and the studies of vitamins in relation to health and development and to reproduction has provided a new approach to determining the functions and requirements of food in human and animal nutrition.

In certain types of feeding experiments with animals the lot or group method has been followed, with no records of feed consumption and response by different individuals. This has been notably the case in pig-feeding experiments, the different lots frequently being fed by means of self-feeders, the choice being exercised by the individual without leaving a record. Individuality and the factor of variation is frequently large, and in order to determine this and the amount of response to the nutrients eaten one station has erected a large series of individual sheds and pens, a single pig to be kept in each and the record of feed and growth secured.

A long-neglected line of investigation relating to the western ranges and their management, their utilization and conservation under grazing conditions, and the place of supplementary feeding, has been taken up lately by a number of the stations. These are studying range vegetation, the factors which affect it, the succession of plants to determine those which eventually will predominate, and the stores of food in roots and crowns throughout the entire period of growth, to get at critical stages for grazing in the life of the plant. Observations are being made on the relative amounts of different forages eaten by sheep and other animals, attempts made to increase desirable range plants by seeding, and the means studied of restoring depleted range through management.

One station in the Southwest has inaugurated an extensive range experiment on a tract of about 62,000 acres, for which Congress recently turned over 55,000 acres. It is determining the carrying capacity of the range, the relation to intensity of grazing, the effect of rotation in range management, and the feeding of cottonseed meal in the winter period of shortage.

In other States of that section and in the Northwest surveys have been made on the economics of stock raising under range conditions, with results of much interest to stockmen. In one State arrangements have been made for detailed studies of the cost of production of beef cattle on ranch and range, based on cooperation with leading stockmen, who will keep records of the various features of their business under close supervision.

Farther east in the grass country extensive pasture experiments have been undertaken, including observations on the carrying capacity, rotative grazing, succession of vegetation, and items of management related to the most efficient use of pasture resources.

In one of the mountain States field experiments have been extended to the higher altitudes on rented tracts varying from 5,200 to 6,600 feet to determine what crops may be grown to advantage, the utilization of limited water supply, and the type of agriculture practicable.

In Maine, where the blueberry represents a million-dollar industry, a tract of land has been secured and a

specialist appointed for the purpose of giving attention to the handling of blueberry barrens, insect control, improvement of the plant, etc. This is in addition to economic investigations of the industry already in progress.

Much attention has been given of late to finding out the practical applications of electricity on farms and in farm homes. Experiments have been instituted in cooperation with farmers in the East and Central West on the types of appliances and operations to which it is suited, the cost of operation, the lightening of labor in the household, and the practicability of supplying a load which will warrant the extension of electric lines through rural communities.

A relatively new line of study pertains to the run-off and its relation to erosion, water losses, and crop production. For this purpose a series of plats has been installed, laid out on different grades and on the level, with equipment for catching the run-off and the silt; also series of terraces maintaining land at level and with varying grades, the water being measured over weirs with settling basins, and contour terraces to hold back the run-off and prevent loss of water and erosion. The entire system of plats and terraces on which measurements will be made embraces about 100 acres and is the most extensive layout of its kind.

An unusually extensive field experiment on fertilizers for oranges in California includes 50 acres with a very comprehensive system of 46 different treatments, each replicated four times. The experiment was laid out with great care, six crops being taken before differential treatment was applied, and records kept on each tree.

An installation has recently been completed in Arizona for studying the water requirements of grapefruit, the water being carried in cement pipes with measuring devices for each plat, and the irrigation based on a point between the water requirement of the soil and the wilting coefficient of the trees.

Among laboratory facilities for making tests and experiments on a factory scale, mention should be made of the flour mills fitted up at at least two stations. These are for making milling tests of wheat of different strains, for experiments on the technology of the milling process, such as tempering different kinds of wheat for varying periods, effect of the degree of maturity of the wheat on the quality of the flour, conditions of storage, etc. Provision is made for control of temperature and humidity of air in the rooms and within the machines, and for other controls of the milling process. By means of such equipment facts of interest to the milling industry are being developed as well as those relating to the actual value of different productions, the proper blending, effects of handling the wheat crop, and other matters.

In connection with studies of cotton, experimental gins are now standard equipment at several stations, and at two points facilities are available for spinning tests under definitely controlled conditions. Such equipment is employed in determining the value of different varieties and selections in the cotton industry, ginning in relation to market and spinning value, effect of the method of harvesting on ginning and spinning quality, and similar questions relating to grade and staple as reflected in the market price.

In connection with the home-economics investigations various new features have been introduced. Among these are the construction of an altitude laboratory for experiments in cooking at atmospheric pressures representing altitudes up to 15,000 feet above sea level; and the devising of an apparatus for testing the protective value of various fabrics for clothing, the quantity of electric energy required to keep a fabric-covered cylinder at a given temperature being measured under different conditions of external temperature and wind movement. The transmissibility through various fabrics of light and the burning rays also is being measured; and one station has equipped a laboratory especially for the study of the effect of sunlight on durability and color of cotton fabrics under various atmospheric conditions.

These are only a few examples of developments which indicate the trends in agricultural investigation. They are significant of the increased intensity in lines long under study, the extension to new fields, reduction to practical conditions, and the application of new means and devices for securing dependable results.

### DEVELOPMENT OF ECONOMIC RESEARCH

The growth of investigation in the field of agricultural economics has gone steadily forward. Never, probably, since the stations were organized, has there been such rapid expansion in any field of inquiry. It has embraced all of the stations except two, and one of these took a prominent cooperative part in a regional investigation. The

subject has received the sympathetic support of directors and been recognized as an essential broadening of the scope of experiment station work.

The personnel in this branch has grown from about 100 persons in 1925, quite largely engaged in the farm management phase, to more than 230 by the close of the second year, including specialists covering the whole range of agricultural economics. The additions have included many persons of broader and more fundamental training than those formerly engaged in the farm management and other economic work of the stations.

The number of projects in agricultural economics has grown very rapidly, so that fully a third of the new projects current under the Purnell Act were in economics and closely related lines. Except for a noticeable tendency to outline large undertakings which often are, in effect, composites covering a group rather than a specific question, the total number of research units would show up considerably larger. Even so, that number far exceeds the new undertakings in any other department of the stations; and the additions in the second year under the Purnell Act represented about 45 per cent of the total new projects in all subjects.

This expansion naturally justifies large expectations, and these expectations are being realized in a satisfactory manner, considering the comparative newness of research in much of this field. Growth in efficiency is to be expected when the subject becomes better organized for research and the standards and methodology are strengthened. These things are quite as important as increase in the number of projects and in assignment of funds. Such growth of ideals, objectives, and procedure will depend on the development of the spirit of research, the attitude and motives of the workers, and recognition of the essentials of broad economic facts as distinguished from current business facts and service information.

That these matters are recognized as important is reflected by the fact that the American Farm Economic Association has a committee working on the subject, and that a section of the Social Science Research Council is analyzing the various types of investigation in the whole field of agricultural economics and giving attention to such matters as methodology, training of investigators, and other essentials.

These surveys by specialists in agricultural economics have led to the conclusion that "such work is very uneven in character," and that if agricultural economics is to occupy its proper place in agricultural research and education "it must become manyfold more scientific and a hundredfold more useful."

The survey of current projects has indicated that work has developed quite largely from the standpoint of individual economic efficiency and profit in production and marketing, while relatively little attention has been given to questions relating to broader economic problems and policies.

To meet the challenge which the opportunity now presents, it is being urged that—

> great effort must be put forward in the years immediately ahead of us to improve the quality of the research work we have in mind, and to direct this research into lines which will produce the hitherto undiscovered facts and principles which underlie the basic problems of agriculture as an essential part of our national life.

These statements are not quoted in criticism of the progress which is making, but as indicating the study which is being given to the future development and strengthening of economic research related to agriculture. This is a hopeful sign, for the changing character of economic conditions and the interest in information in that field may tend to hold back the development of more fundamental investigation and perpetuate a noticeable difference between it and research in the older lines of agricultural science.

A considerable volume of the economic inquiry at this stage is directed to surveys to disclose the existing situation with reference to supply and demand and their elasticity, market prices, and a wide range of matters relating to current economic conditions. Its purpose is to acquaint the public and the workers themselves with the facts as they exist under present conditions, ostensibly as a background for projecting investigation. Such information has at least a temporary application, interpreted as applying to local and current conditions, and it has a value to the investigator like that attached to analysis of current statistics; but in themselves the data lack the permanence of fact which obtains in research in the natural sciences related to production, and probably can not attain that permanence because of fundamental differences between economics and the natural sciences.

Such projects assist in working out the methods essential to accuracy, and the background which they supply en-

ables a better understanding of problems and of the factors they embrace. Considerable importance is attached to this type of work, and it is frequently designated as fact-finding inquiry. But it may be expected that this work now will become a study of what the situation actually reflects, of the causes lying back of it, of the consequences or the reaction that may be expected. In other words, the aim of economic research, like investigation in other branches of science, will be more and more the discovery of causal relations.

In the beginning it is quite natural that the general and descriptive type of investigation should predominate, but its nature and reach must not be overestimated in the permanent effort. There will be need for recognizing the difference between a current business fact and an economic relationship of considerable range and permanence; and it will be important to develop forward-looking plans for working out some of the more permanent and far-reaching economic facts and principles.

In other branches research at present is less concerned with empirical facts applying to a particular condition and locality than it is with getting facts that have a broader and more general significance, pertain to certain defined conditions, and contribute to intelligence and understanding upon the subject. The farming people need current statistical facts, interpretations as to probable effect of conditions prevailing at the time, and similar help, but they also need for their guidance, especially in group operations, a more permanent type of information which may give them ability to interpret the facts supplied them and judgment in planning long-range operations. Such a product will likewise constitute the basis of teaching.

The accuracy and reliability of the data on which such economic studies are based may prove quite as important as in any other branch of investigation, if generalities are sought. Evidently the results developed by statistical methods are not more reliable than the data they are based upon, and, under current procedure, these data often leave considerable to be desired. The line between economic research and the supplying of economic facts may not be a very sharp one with respect to a particular subject or stage, but it is important to see the distinctions clearly if research is to grow. A business analysis of a group of farmers may be mainly a personal service to those concerned, or it may be made to develop economic facts of considerable range. This depends on the motive and the element of inquiry involved. It is a matter of aims and standards with the investigator.

That there is difference of opinion and some confusion is frequently indicated by current projects. The statement may contain such objectives as "to determine" and "to evaluate," but may end with the modified announcement that "the data will be analyzed by standard statistical methods in a manner which will throw as much light as possible on the objectives set forth."

Some proposals seem to constitute parts of a system for covering the various localities of a State—not merely types of farming or geographical conditions but local groups of individuals. Again, there have been proposals for the operation of farms to demonstrate a method or to set up a model farm, as for dairying. Another type of projects deals with the cataloguing or describing of enterprises in the large, ostensibly to get a broad view and to study some cause-and-effect relationships, but not always reaching so far in actual execution because of the impracticable scope of the undertaking. Such proposals are illustrated, for example, by surveys of all the cooperative enterprises within a State, without regard to class or character, by studies of the marketing of all agricultural products in a State, and the like.

These things are characteristic of investigation in a new field. They are a part of the means by which clearer understanding of the field and the methods of economic inquiry are being worked out. What is learned from them will be an important product of this stage. Hence they will need study with that end in view. For research is a process of growth as well as a means of it, and the standards and methods must grow with and out of it. The end is never reached; each step of progress opens up new lines of advance, frequently calling for new procedure. As the conclusions from economic investigation can not be submitted to the same kind of tests that prevail in other lines, the development of criticism is desirable to free the inquiry from personal bias and thus, while assembling evidence, to build constructively.

### RESEARCH IN RURAL SOCIOLOGY

Studies in rural sociology remain one of the smaller of the research activities of the stations, but there is encourag-

ing progress in developing this field of investigation. There was some increase in projects and substantial progress in developing methods of research. Twenty-five projects at 14 stations were recorded as active during the year. These projects related largely to factors affecting the well-being of rural communities as reflected in standards of living, community organization and development, including organization meeting the needs of rural youth, relation of town and country interests, rural leadership, and movement of the farm population.

Question is often raised as to the adequacy of the methods used in rural sociological research. It is evident that rural sociologists are alive to the weaknesses and limitations of their methods and the difficulties which must necessarily be encountered in their field of investigation, and are earnestly endeavoring to put their work on a sound scientific basis.

A significant event of the year was the holding of a conference on research methods in rural sociology at Purdue University, April 4 to 8, 1927, attended by representatives of 21 experiment stations and the Department of Agriculture, besides other institutions and agencies interested in the subject. This conference grew out of the fact that while it was generally agreed that the field of rural sociological research needed "immediate and extensive study," there was uncertainty as to the methods and procedure to be followed and the definitions, terminology, and technic to be used. Its primary purpose was to offer a definite program of developing the best ideas available as to the organization and conduct of research in this field, with specific reference to the work already under way or in contemplation. Individual projects completed or in progress were discussed, as were four general projects outlined by a committee of the conference with suggestions as to how they might best be carried out. The subjects of these general projects are (1) young people's organizations as a factor in rural life, (2) factors influencing the effective location of rural groups, (3) the rural population—composition and changes, and (4) the standard of living of farm families.

### HOME ECONOMICS RESEARCH

The year 1926–27, the second year of operation of the Purnell Act, was marked by a development and strengthening of the home economics research already under way rather than a rapid expansion of the work. With a total of 39 States in which research under the Purnell Act is being conducted there appears to be no lack of interest in and support for this new work. That it has aroused interest throughout the entire country is evident from the numerous requests received by the Office of Experiment Stations from organizations, institutions, and individuals for information on the scope and progress of the work. Home economics students working for advanced degrees in colleges and universities are becoming interested in research as a profession and are definitely fitting themselves for the work. The American Home Economics Association, in recognition of the expansion of research resulting chiefly from the Purnell Act, authorized an expansion of the Journal of Home Economics to include a research section devoted to reports of research in various phases of home economics.

Progress in the 90 or more projects under way has of necessity been slow. The establishment of rat colonies for the vitamin studies conducted in 14 States has required considerable time, but with well established colonies results will soon be forthcoming. Preliminary accounts have already appeared in the annual reports of various stations, as well as two or three papers on completed studies. The vitamin studies range from simple determinations of the vitamin content of locally grown foods hitherto not studied, to more fundamental studies on the effect of cultural methods, degree of maturity and manipulative processes on the vitamin content of food materials, and still more fundamental research on the ultimate sources of vitamins and the influence of vitamins on the utilization of other food essentials.

The miscellaneous projects in foods and nutrition range from the purely practical to essentially theoretical, but there has been a gratifying tendency in the former to depart from the trial and error methods which characterized experimental cookery in its earlier stages to the establishment of definite principles of general application. Bread-making studies afford a good example of this. At the Arizona station methods successful not only on a small household scale but on a commercial bakery scale have been developed for the use of the Early Baart wheat, and this has been accomplished not by repeated alterations of the proportions of ingredients but by a chemical study of the flour and dough from

the standpoint of H-ion concentration, buffer value, and diastatic activity.

The problem of high altitude cookery is being met at the Colorado station by the construction of an altitude laboratory, in which pressure conditions comparable to those of any altitude from 15,000 feet above sea level to 5,000 feet below sea level can be maintained, with the introduction of no other variable. Baking studies conducted in this laboratory will establish standards for use in any altitude in the United States and will thus furnish valuable information for use throughout the country. Numerous other projects might be cited as showing a combination of the practical with the theoretical.

The West Virginia project on methods for the economic utilization of surplus food products has not only been the means of standardizing blackberry jam, the preparation and sale of which is an important home industry in the State, but has also developed into a study of the blackberry pectin and the principle involved in the making of jelly from blackberries.

Brief mention should be made of the cooperation of home economics departments in the national cooperative project on factors affecting the quality and palatability of meat, since this has involved not merely the cooking of the meat for the palatability tests but the development of standard methods of cooking. At Minnesota standard methods have been developed for pork; at North Dakota for veal.

Ranking next in number of projects to the laboratory studies in foods and nutrition are the 30 or more projects coming under the general scope of rural home management studies and including studies on food consumption, use of time, equipment, and standards of living and expenditure. Practically all of these form a part of the national cooperative rural home management studies and follow more or less closely the outlines proposed by the committee on this subject. These projects, with the exception of the equipment studies, have for the most part been conducted by the survey method, and as such have depended for their success upon the ability of the research worker to make a proper selection of samples to conduct the survey intelligently and to analyze the data when once secured. Experience has shown that a knowledge of economics and of statistical methods is almost a necessity in such work, and there have been instances where lack of this knowledge has worked disaster.

A few of the food-consumption studies have been completed and the results published. Such a study in Mississippi has shown a marked deficiency in iron in the food consumption of the people of the State. This discovery has led to a laboratory investigation having for its ultimate goal an increase in iron consumption through a greater knowledge of the relative iron content of vegetables grown in the State and of improved methods of cooking these vegetables to conserve their iron content. Most of the rural home management studies have not progressed sufficiently for general conclusions to be drawn concerning them.

Closely allied with the food-consumption habits of farm families are the several studies, also conducted by the survey method, of dietary habits of school children with relation to their health. As an illustration of this may be cited a study at the Massachusetts station of the dietary habits and health, as determined chiefly by the condition of the teeth, of the school children in two different types of rural districts in the State—one a cranberry-growing district near the coast and the other a dairy section in the Connecticut Valley. This study showed a positive correlation between the good condition of the teeth and the degree of milk consumption. The study brought out the unsatisfactory nature of the school lunches taken by most of the children in consolidated schools and led to another project entitled "Present practices of Massachusetts consolidated elementary rural schools with regard to school feeding and transportation and their effects upon the health of pupils." It is an encouraging sign that in a number of instances one project in its development has not been an end in itself but has pointed the way to others whose necessity and value might not otherwise have been realized.

An almost unexplored field of research in home economics is that of textiles and clothing. Lack of trained workers in this field and of knowledge of what really constitutes research have been the factors making for slow progress. Studies dealing with the transmissibility of light by different fabrics have been reported from the Utah and Kansas stations, the investigation at the latter place also including the transmissibility of heat. The importance of chemistry and physics in textile research is being realized more and more, and the success of the research along these

lines has been due largely to the cooperation of the physics departments. At the Texas station a well-equipped textile laboratory is being established and the initial study to be conducted is on the effect of Texas sunlight on the durability of various fabrics.

On the whole the outlook for home economics research is most encouraging. The most hopeful signs for its success in the future appear to be the increased interest in the colleges and universities in the training of future workers for the field; the realization on the part of those in charge of the work of the necessity of appointing efficiently trained workers; the interest and cooperation of other departments at the stations; and, above all, the encouragement and support given to this new field of research at the experiment stations by the directors themselves.

## PROJECTS

The total number of projects in active operation at the stations during the year was 6,186, of which 465 were Adams projects and 788 Purnell projects. Thirty-five new Adams projects and 235 Purnell projects were added during the year.

Of the active Purnell projects, 42 dealt with soils and fertilizers, 16 with genetics, 43 with field crops, 52 with horticulture and forestry, 38 with plant diseases, 40 with entomology and zoology, 97 with animal production, 35 with dairying, 19 with animal diseases, 22 with agricultural engineering, 92 with home economics, 245 with agricultural economics, and 25 with rural sociology. The number of projects per station range from 6 to 28, the average per station being over 16. It will be noted that nearly one-half (362) of the Purnell projects were in the fields of agricultural economics, home economics, and rural sociology.

### FORMULATION OF PROJECTS

Recognition of the value of carefully considered and formulated project plans as an aid to the investigator as well as to the administrator is evident from the fact that every station has a project system of some kind. The project outline as a means of formulating and defining a scientific inquiry has come into general use. It is an evidence of clearer and more deliberate planning, and of more systematic, ordered effort. While it is not a thing to be standardized, it may be expected to conform to certain essentials which experience and good usage have disclosed. The policy and procedure followed in formulating projects, however, differ widely.

In the opinion of the committee on experiment station organization and policy of the Association of Land-Grant Colleges and Universities,[2] "there is still need for more careful scrutiny on the part of project leaders and administrative officers in outlining new research projects so as to insure 'concrete investigations of such limited range as to make them feasible of accomplishment' within reasonable time." The committee makes the following pertinent suggestions:

> Whatever the method of procedure the leader of the proposed project should assume responsibility for knowledge and analysis of previous investigation, or investigations under way, which may have a bearing on the research proposed by him. In like manner he should be prepared to support his proposed methods of investigation as adequate for accomplishment in the research proposed, and feasible of being carried out with the facilities and equipment which may be made available.
>
> After thorough consideration of these matters, the next important task is to formulate a project statement which pictures for administrative officers, other investigators, and coworkers the merits of the project, its objective, procedure in the proposed investigation as to technique and methods, the probable period of time and its reasonableness, and the funds required and their adequacy for the proposed work.

The committee makes the following concrete recommendations regarding the policy which should be followed in the formulation of new projects:

> *The title.*—This should characterize the concrete, limited unit of work to be undertaken and not cover the entire field to which the project is related.
>
> *The objective.*—It should be clear cut and specific, and not involved with statements of procedure.
>
> *The outlook.*—The project should be constructive in character. It should take account of the status of the question, attack points which need further study, supplement other work, exhibit vision and ingenuity, and give prospect of success.
>
> What, specifically, is it proposed to add to the sum of knowledge of the subject? Such a contribution may deal with some new point, or those still in doubt, or determine applications to the conditions in the region.
>
> *The procedure.*—It should be up to date, representing the progress and current views on methods and technique. It should give data that will stand statistical analysis and be comparable with other similar accepted data. Does it cover the requirements of the subject, or is it one-sided or inadequate in some respects?

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[2] ASSOCIATION OF LAND-GRANT COLLEGES AND UNIVERSITIES. PROCEEDINGS OF THE FORTY-FIRST ANNUAL CONVENTION . . . HELD AT CHICAGO, ILL., NOVEMBER 15–17, 1927, p. 195–197. Burlington, Vt. 1928.

*Thoroughness.*—The project should be designed to undertake thoroughly and with reasonable completeness the investigation of the subject and should not be fragmentary and superficial.

*Probable duration.*—Is the time element a reasonable one? Does the project commit the station to a course it may not be desirable to carry through?

*The funds required.*—Is the estimate ample for the proposed investigation? Are the expenses and other essentials within the means of the station budget?

It is evident that the actual formation of the project should be preceded by a careful analysis of the problem to be studied to determine the relative importance of its constituent elements and the order in which they should be taken up. It is also necessary to carefully consider whether the data it is expected to obtain are statistically competent and reasonably certain to establish the objectives sought, and provision should be made for digesting the data as investigation proceeds to determine whether and in what direction it is progressing.

## COOPERATION

The increasing support of the stations makes possible not only an expanding research program but also broader and more effective cooperation. The growth of cooperation is one of the most significant and promising developments in agricultural research at the present time. It is evidence of a desire for concerted study of important problems which is doing much to hasten their solution.

The cooperative work of the station falls into four main classes, as follows: (1) Cooperation between station departments, (2) cooperative work within the States, (3) cooperation between stations, and (4) cooperation between the stations and the Department of Agriculture. In addition there is some cooperation by the stations with outside agencies, such as commercial establishments and organizations, in the study of special problems.

The interrelations of the sciences involved in agricultural research makes interdepartmental cooperation within the station in many cases not only desirable but imperative, and there are many excellent examples of effective cooperation of this kind. Every station has more or less cooperative work within the State, and this has been greatly aided through the organized effort of so-called experimental unions and similar organizations made up largely of former agricultural students. Similar aid to cooperative work in home economics is one of the promising possibilities. Regional and national cooperation is not a new development, but has been given considerable impetus by the Purnell Act. Some of the cooperative projects of this kind which have been entered into since the Purnell Act went into effect are beginning to show results which demonstrate the advantage of attempting to solve some of the large problems by this means.

The national cooperative projects selected by the St. Louis conference in April, 1925, as appropriate for Purnell fund support have been actively carried on by a large number of the stations and the Department of Agriculture. The total number of individual station projects recorded as contributing to these national projects was 182, distributed as follows: (1) Marketing and surpluses, 93; (2) vitamins in foods, 24; (3) rural home management, 21; (4) rural social organizations and agencies, 24; and (5) factors influencing quality and palatability of meat, 20.

In all, 630 projects, or approximately 10 per cent of the total number of station projects, are recorded as carried on cooperatively with the department. These include all of the major subjects in agriculture and practically all the bureaus of the department, as well as every experiment station, some stations taking part in 10 or more enterprises of this kind. The projects are distributed by subjects as follows: Soils, soil fertility, and fertilizers, 53 at 25 stations; plant improvement, 23 at 17 stations; plant genetics, 7 at 7 stations; cereal, forage, and other field crops, 47 at 25 stations; pastures and ranges, 5 at 5 stations; horticulture and pomology, 16 at 9 stations; plant diseases, 25 at 18 stations; animal production, 89 at 38 stations; animal pathology, 2 at 2 stations; animal genetics, 1; dairying, 34 at 20 stations; entomology and zoology, 95 at 41 stations; home economics, 4 at 3 stations; agricultural engineering, 35 at 13 stations; forestry, 17 at 5 stations; agricultural economics, 151 at 42 stations; rural sociology, 23 at 15 stations; and meteorology, 1.

Nearly one-fourth of the cooperative projects are in agricultural economics, marketing of farm products leading, with 25 per cent of the projects, or over 6 per cent of the total number of projects recorded for all lines of investigation. This is in line with the expectation that the Purnell

Act would not only give rise to a greater development of the cooperative relations between the department and the experiment stations, but that it would be especially effective in the newer field of agricultural economics.

In home economics only a few definite cooperative agreements between the department and the stations have been recorded, but the Bureau of Home Economics has participated in an informal way in work on this subject, especially in household management, at many of the land-grant institutions.

Cooperative work between the department and the stations has been carried on to a certain extent practically since the stations were established. For many years this work was based largely on verbal and informal agreements. However, as the cooperative relationships have increased in number and become more involved in character, the need of an explicit understanding as to the part which each cooperator is expected to take, the responsibility each is to assume, and how the results are to be published has become evident, and formal agreements have in large measure taken the place of informal understandings.

The broader and more effective cooperation between the stations and the department, made possible by the increasing Purnell funds, is resulting in marked progress in the solution of some of the larger national problems of agriculture and the farm home.

## FINANCIAL SUPPORT

The upward trend in funds available for support of the work of the stations, which began in 1925 after a period of sharp decline, was maintained during the year. The present situation is in general a gratifying one despite the fact that in a few cases there has been shown some disposition to reduce State support as the income from Federal sources increased by the operation of the Purnell Act, thus nullifying to a certain extent the real advantage from increase of funds under that act.

The total income of the stations for the fiscal year 1927 was $13,101,747, as compared with $12,191,288 the previous year. This includes $720,000 each from the Hatch and Adams Acts, $1,440,000 from the Purnell Act, and $233,980 for the support of the experiment stations in Alaska, Hawaii, Porto Rico, Guam, and the Virgin Islands. The remainder, $9,987,767, was derived from other than Federal sources, including State appropriation, fees, sales, and miscellaneous sources, as shown on pages 116–117.

## USE OF THE PURNELL FUNDS

### DISTRIBUTION BY LINES OF WORK

Approximately 35 per cent of the Purnell fund of $1,440,000 was assigned to studies in agricultural economics, 13 per cent in home economics, and 3 per cent in rural sociology. As regards subjects of investigation, the fund was expended approximately as follows: Agricultural economics, $507,500, or 35.2 per cent; home economics, $184,400, or 13 per cent; animal industry, including poultry husbandry and animal nutrition, $166,960, or 11.5 per cent; field crops, $87,450, or 6 per cent; soils, fertilizers, and soil fertility, $73,410, or 5.1 per cent; horticulture, $72,890, or 5 per cent; entomology $67,850, or 4.7 per cent; plant pathology, $57,400, or 4 per cent; dairy industry, $57,135, or 3.95 per cent; rural sociology, $45,880, or 3.2 per cent; agricultural engineering, $42,700, or 3 per cent; plant genetics, $25,650, or 1.8 per cent; animal diseases, $22,450, or 1.56 per cent; agricultural chemistry, $14,890, or 1.03 per cent; and forestry, $1,000, or 0.07 per cent. The remaining amount of $12,435, or 0.89 per cent, was spent for the printing of the results of Purnell fund studies and for travel and other authorized expenses in connection with Purnell work in general.

### CAPITAL EXPENDITURES AND OVERHEAD CHARGES

In the administration of the Purnell Act effort has been made to maintain the general principle laid down in the department's original announcement that since the new fund was for "the more complete endowment and maintenance of agricultural experiment stations," the existence was recognized of an experiment station in each State as a going concern, with an organization, administrative machinery, buildings, land, and other facilities for research. This view does not anticipate drawing on the Purnell fund for building operations of a permanent character, the purchase of additional lands, purely administrative expenses, prorating of general overhead expenses for maintenance of plant, and general service charges by the institutions with which the stations are connected.

On the whole the capital expenditures from that fund have been relatively small, aggregating for the past

year $21,441. Seventeen of the States made no assessment for that purpose, 18 others used less than $500, and only 6 used over $1,000, the amounts in the latter cases running up to the full percentage of the appropriation allowable in that year, $3,000.

While this is a gratifying showing, there has been occasional evidence of a disposition to shift financial responsibility from the State to this new fund in providing additions to the plant essential to expansion, or in undertaking such expansions without waiting for State appropriations to meet the requirements. In individual cases expenses have been incurred in the past which, while legally within the act, are not in harmony with the spirit in which it was sought and passed. In one instance a tract of land was bought at an expense which necessitated the division of the purchase price between two fiscal years. Again, entire buildings have been remodeled because no State funds were available for providing room required for the enlargement of staff and range of activities. And in other instances permanent structures suitable for general purposes have been provided out of this fund for investigation.

In the effort to check such tendencies as they came to light, attention has been called to the department's interpretation, with a result which often has been effective. Except in rare instances the full 10 per cent permitted by the act to be used for necessary buildings and land is in excess of the special current needs of new projects. To assess the fund for a new poultry plant or for additional land because experiments more or less temporary in nature are undertaken not only reduces the amount available for conducting investigations but fails to recognize the State's part and sets dangerous precedents. With the funds still growing and authority to use up to 10 per cent for capital expenditures, the pressure on State administrative officers is likely to become heavy. Hence attention will continue to be given the matter, and the department's influence used toward conservatism, with emphasis on the special needs of accepted projects.

Charges for general administration have not been regarded as permissible on either the Adams or Purnell funds, although proposals have not been infrequent. While increase in the number and diversity of projects and the attendant business naturally enlarges the administrative responsibilities, these acts were designed and accepted for purposes of research, on the assumption that the increased administration and accounting would be cared for by the institutions and not be a tax on the special grants.

Some disposition has been noticeable of late to assess the stations for their pro rata share of expense on account of such items as heat, light, water, library, and other services supplied by the parent institution. Formerly such charges were made by a number of colleges, but with the more definite recognition of the station as a department of the college, and the provision of funds for the maintenance of the plant of the entire institution, there has been a general disposition to remit such charges. Such a course seems logical, recognizing no distinctions between the research functions and other types of activity of a modern educational institution.

In establishing and seeking aid for experiment stations the colleges assumed a measure of responsibility for providing the necessary environment and facilities. While the demands have grown with the enlargement of the station operations, these are probably not out of harmony with the growth in the college plant as a whole, which has resulted in recognition of the need of increasing funds to cover overhead expenses. The maintenance of this broad principle of responsibility and of obligations of the States will help to conserve the Federal funds more definitely for the carrying on of research.

## PERSONNEL

The number of station employees during the year was 2,831. Since the passage of the Purnell Act in 1925 the stations have increased their personnel by some 430 permanent workers, a large proportion of the new appointees being in the field of agricultural economics and rural sociology and home economics, viz, 98 in agricultural economics, 15 in rural sociology, and 65 in home economics.

Nearly one-half of the station employees have other more or less engrossing college duties. There is, however, an evident disposition to lighten the teaching load, so arrange teaching schedules, and adjust other duties that they will interfere as little as possible with research. The proportion of the new appointees and of the key men in research who are free from other duties has grown considerably. As a result the increase in effective man power for research is greater than the

increase in number of workers would indicate.

### CHANGES IN PERSONNEL

The major changes in personnel during the year were as follows:

**Changes in directorships.**—There were no permanent changes in directors. E. D. Merrill, director of the California station, was granted a partial leave of absence during the year beginning June 1, 1927, to permit him to act in the capacity of director of the newly established botanical gardens at Los Angeles. In his absence W. L. Howard, director of the branch of the college of agriculture at Davis, served as acting director of the station. E. J. Iddings, director of the Idaho station, was given six months' sabbatic leave for the purpose of studying agriculture in foreign countries, with special reference to the field of animal industry. The plant pathologist of the station, C. W. Hungerford, served as acting director during this period. F. B. Linfield, in addition to his duties as director of the Montana station, was appointed acting president of the college during the absence of the president, who was granted a year's leave for travel and study. E. A. Burnett, director of the Nebraska station, was made acting chancellor of the university, and W. W. Burr, head of the agronomy department, was appointed to act as director of the station. The director of the Texas station, B. Youngblood, was given a two years' leave for work on cotton-marketing problems in this department. A. B. Conner, the vice director of the station, was made acting director.

**Other changes.**—J. D. Pope was transferred from the extension service to the Alabama station staff as agricultural economist, assuming his duties July 1, 1926. Georgia W. Burton, in charge of research work in home economics, resigned in June, 1927.

At the Arizona station O. C. Magistad succeeded W. T. McGeorge as associate chemist, effective February 18, 1927, and W. G. McGinnies was appointed grazing range specialist.

The Arkansas station appointed G. H. Banks as assistant director in charge of the newly established branch station for rice culture at Stuttgart, and G. W. Ware as assistant director of the fruit and truck station at Hope.

G. H. Hart, veterinarian at the California station, was transferred to the branch of the college of agriculture at Davis as head of the division of animal husbandry, entering upon his duties July 1, 1926. B. A. Madson, associate agronomist at Davis, was appointed head of the division of agronomy, succeeding J. W. Gilmore, who relinquished his administrative duties to continue research work at the university farm. L. J. Fletcher, chief of the division of agricultural engineering, resigned December 31, 1926. R. L. Adams, head of the division of farm management, resumed his duties after a leave of absence spent as director of markets in the State, and W. P. Tufts, associate pomologist, returned from the University of Wisconsin, where he took advanced work for the doctor's degree. Frank Adams, irrigation economist, was granted a six months' leave to serve as expert adviser in connection with the study of the economic agricultural and industrial development work in Palestine. Appointments in the rank of associate at the station included F. N. Briggs in agronomy, Blythe F. Monroe in soil technology, G. A. Richardson in dairy industry, and P. F. Nichols in fruit products.

Among the major appointments at the Colorado station were those of F. B. Smith, associate agronomist; H. C. Hanson, associate botanist, and Mrs. Marjorie J. Peterson, home economics investigator. R. A. McGinty, associate in horticulture, was granted leave for advanced study.

The Connecticut Storrs station granted leave of absence to L. C. Dunn, geneticist, and to G. C. White, dairy husbandman. J. L. Hypes and W. E. Stemmons, of the college faculty, were added to the station staff, the former as sociologist and the latter as editor. Elizabeth V. W. Clapp was appointed home economist.

M. R. Ensign was transferred from the extension service to the Florida station staff as horticulturist in truck-crops investigations and A. F. Camp, plant physiologist, was made associate horticulturist. Other appointments included M. N. Walker as cotton specialist for work in physiological and pathological investigations, L. W. Gaddum as biochemist in home economics, and R. V. Allison as soil specialist at the Everglades branch station.

At the Georgia station Susan J. Mathews, who had been devoting half time to research work in home economics, was appointed a full-time worker. R. C. Campbell was appointed cotton-fiber specialist, assuming his duties July 1, 1926.

G. L. A. Rueble was appointed bacteriologist at the Idaho station, effective September 15, 1926, succeeding W. M. Gibbs, resigned. R. C. Engberg

was made associate in agricultural economics.

Appointments at the Illinois station included R. C. Ashby, assistant chief in livestock marketing; C. A. Brown, associate in dairy economics; J. B. Andrews, associate in farm organization and management; and W. P. Flint, consulting entomologist. The resignations were reported of C. S. Crandall, chief in plant breeding; A. H. Karraker, associate in soil survey experiment fields; and C. A. Garner, associate in olericulture.

At the Indiana station the department of agronomy was reorganized to include the sections of soils and crops and agronomy, and A. T. Wiancko, the station agronomist, was elected chief of the new department. G. H. Cutler was appointed assistant chief, effective September 1, 1926. The position of State chemist and seed commissioner was filled by H. R. Kraybill, and Miriam Rapp was appointed to take charge of the Purnell projects in home economics. Laurenz Greene, head of the department of horticulture, was granted a year's leave of absence to be spent in a study of the fruit and vegetable marketing problems of the western coast. L. P. Doyle, associate animal pathologist, and H. D. Brown, associate in vegetable gardening, resumed their duties after a year's absence spent in advanced study.

F. W. Beckman, editor for the Iowa station, resigned February 1, 1927, his associate, Blair Converse, succeeding him as head of the division. E. V. Abbott was appointed assistant chief in soil chemistry and bacteriology, and J. B. Wentz and P. Mabel Nelson, of the college faculty, were added to the station staff, the former as assistant chief in farm crops, and the latter as assistant chief in home economics. O. H. Elmer, assistant chief in plant pathology, resigned. E. W. Lindstrom, head of the division of genetics, was granted leave of absence for work in Europe in cooperation with the International Education Board.

At the Kansas station Millard Peck was appointed to fill the vacancy in land economics caused by the resignation of Eric Englund. A. E. Aldous was placed in charge of pasture-management investigations at this station, and Margaret S. Chaney and Verral J. Craven were added to the staff for work in food economics and nutrition. H. B. Walker, head of the division of agricultural engineering, was given a year's leave of absence, beginning March 1, 1927, to act as director of research in mechanical farm equipment in this department. R. H. Driftmier, associate agricultural engineer, was in charge of the division during this period. R. W. Titus, associate in feed analysis, was granted leave for graduate work. J. H. Parker, plant breeder, returned to his duties October 1, 1926, having spent a year in advanced study at the University of Cambridge, England. E. C. Converse, meteorologist for the station, died January 22, 1927.

O. B. Jesness, chief of the section of markets at the Kentucky station, was made head of the new department of markets and finance.

The Louisiana station appointed H. B. Brown as cotton specialist and C. B. Gouaux as specialist in charge of sugar test fields, succeeding in this work D. N. Barrow, who was elected station agronomist. C. L. Osterberger of the college faculty was transferred to the station staff to carry on experiments with farm machinery. Resignations reported were those of F. C. Old, head of the poultry department, and H. W. Manter, parasitologist.

J. W. Gowen, biologist at the Maine station, resigned in July, 1926, to become an associate member of the Rockefeller Institute for Medical Research, but continued to hold a collaborating connection with the station. W. F. Dove was appointed associate biologist, and B. T. Smith, associate agricultural economist, resigning this position later in the year.

Margaret Coffin was appointed research home economist at the Maryland station. F. H. Leuschner, associate poultry husbandman, resigned.

R. J. McFall was transferred from the extension service to the Massachusetts station staff as research professor of agricultural economics, effective August 1, 1926. This position he resigned on June 1, 1927, to go to the United States Department of Commerce. Other resignations included Henry Van Roekel, specialist in poultry disease elimination, and A. W. Phillips, in dairy manufacturing.

At the Michigan station R. Wayne Newton was appointed research associate in agricultural economics and C. R. Hoffer, of the college faculty, was added to the station staff as associate in rural sociology. A. J. Patten, the station chemist, was granted a leave of absence for work with a milling company in the State, and G. M. Grantham, research associate in soils, was given a year's leave for graduate study.

A. G. Ruggles, entomologist at the Minnesota station, was made acting chief of the division during the absence of R. N. Chapman, and Jane M.

Leichsenring was appointed as nutritionist in home economics. Leave of absence was granted to G. A. Pond, associate in farm management, and to J. J. Willaman, associate in agricultural biochemistry. In June, 1927, the degree of doctor of science was conferred by the Kansas Agricultural College on Andrew Boss, the vice director of the station.

In addition to his duties as head of the animal husbandry department, G. S. Templeton was made assistant director of the Mississippi station. Olive A. Sheets was appointed food specialist in the home economics department.

At the Missouri station Mabel V. Campbell was appointed head of the home economics work, entering upon her duties September 1, 1926.

C. A. Brennen was appointed range economist at the Nevada station, effective June 1, 1927, to give specific study to the economics of cattle production on ranch and range.

W. C. Thompson, head of the poultry department at the New Jersey stations, resumed his duties September 1, 1926, after an absence of two years spent at the National Poultry Institute of the Harper Adams Agricultural College in England. A. G. Waller, research specialist in agricultural economics, was made chief of the section, succeeding Henry Keller, who relinquished station duties to devote his time entirely to instructional work in the college. H. B. Sprague was appointed agronomist, effective May 1, 1927, vice G. W. Musgrave, resigned. R. P. White and H. M. Biekart were added to the staff, the former as floricultural pathologist and the latter as associate in ornamental horticulture. During the past year the office of secretary and editor was divided. The secretary, C. R. Woodward, was succeeded in the editorial work by his associate, R. W. DeBaun. Mrs. Herminie B. Kitchen was promoted from assistant to associate editor.

The New Mexico station appointed W. E. Watkins as nutrition chemist in the department of animal industry.

At the New York Cornell station leave of absence was granted H. C. Thompson, head of the department of vegetable gardening; F. G. Behrends, in rural engineering; Charles Chupp, in plant pathology; G. F. Heuser, in poultry husbandry; and L. H. MacDaniels, in pomology.

At the New York State station G. P. Van Eseltine was appointed associate in research horticulture vice Alwin Berger, resigned. H. B. Tukey, in charge of the orchard-management work in the Hudson Valley, was transferred to the main station as acting chief in research horticulture and placed in charge of the new investigations with nursery plants and shrubs, assuming his duties in April, 1927. He was succeeded in the fruit-investigation work in the Hudson Valley by L. C. Anderson. G. J. Hucker, associate bacteriologist, was awarded a fellowship by the International Education Board, and left the station in August, 1926, to take up work in Europe.

Constance Leeby was appointed research specialist in home economics at the North Dakota station.

C. J. Willard and W. G. Stover, of the faculty of Ohio State University, were added to the Ohio station staff, the former as associate in agronomy, and the latter as associate in plant pathology.

J. O. Ellsworth was placed in charge of the research work in farm management at the Oklahoma station, entering upon his duties August 1, 1926. Jessie E. McMahon was appointed for research work in nutrition and dietetics, resigning this position in June, 1927, on account of ill health. L. D. Howell, associate agricultural economist, resigned to come to this department.

At the Oregon station M. N. Nelson was appointed chief in agricultural economics, effective August 1, 1926. J. R. Haag succeeded H. G. Miller as chemist in nutrition, assuming his duties January 1, 1927.

W. H. Tomhave, head of the animal husbandry department of the Pennsylvania station, resigned June 30, 1927. T. B. Charles was appointed associate poultry husbandman, assuming his duties July 1, 1926. In addition to his duties as experimental agronomist, C. F. Noll was made superintendent of farms, vice C. L. Goodling, resigned.

Margaret Whittemore succeeded Mrs. W. L. Hines as home economist at the Rhode Island station. H. G. May, head of the research work in animal breeding and pathology, died December 23, 1926.

A division of poultry husbandry was established at the South Carolina station, with C. L. Morgan, former associate professor of animal husbandry, in charge. T. S. Buie, acting head of the division of agronomy, was granted a year's leave for graduate study, during which time R. W. Hamilton, extension agronomist, served as acting chief. A. M. Musser was appointed acting chief of horticulture, E. H. Rawl suc-

ceeding him as associate horticulturist. Mary E. Frayser was appointed specialist in home economics research, reporting for duty September 1, 1926.

A. L. Bushey, for several years connected with the South Dakota station as agronomy analyst, died June 6, 1927. T. R. H. Wright, of the extension service, was transferred to the station staff as associate animal husbandman.

Appointments in the rank of associate at the Tennessee station included H. L. Fackler in entomology, H. P. Ogden in agronomy, and G. A. Shuey in chemistry. Elizabeth Cheatham was appointed librarian.

The Texas station appointed Jessie Whitacre chief of the division of rural home research and P. C. Mangelsdorf agronomist in charge of corn and small-grain investigations. W. B. Lanham, chief horticulturist, resigned June 1, 1927, to come to this department. B. F. Dana was appointed plant pathologist, with location at the Temple substation. R. H. Stansel succeeded V. E. Hafner as superintendent of the Angleton substation, and E. W. Thomas was made superintendent at the Sonora substation vice E. M. Peters, resigned.

R. J. Becraft, in charge of range-management investigations at the Utah station, resumed his duties after a year's absence spent at the University of Chicago.

H. P. Young was transferred from the extension service to the Vermont station staff as agricultural economist, effective September 1, 1926, and T. L. Hills was appointed as microscopist. L. S. Walker was made chief chemist in commercial feeds and fertilizers, entering upon his duties May 14, 1927.

Appointments at the Virginia station included F. W. Hofmann as associate horticulturist, effective July 15, 1926, and V. R. Hillman as investigator in rural electrification, effective January 1, 1927.

J. L. St. John, chemist at the Washington station, and E. F. Dummeier, agricultural economist, returned to their duties after a year's absence spent in graduate work. H. L. Garver was appointed investigator on the relation of electricity to agriculture.

T. L. Harris was appointed rural sociologist at the West Virginia station, and F. E. Chidester, of the university, was added to the staff as zoologist. Hazel Cameron succeeded Ruth Buchanan as research home economist, and J. H. Rietz was appointed veterinarian, entering upon his duties January 1, 1927. H. E. Knowlton, associate horticulturist, was made acting head of the department.

The Wisconsin station added W. A. Hartman and P. E. McNall to the staff for research work in agricultural economics.

At the Wyoming station Otto McCreary was appointed associate chemist, and Edith G. Grundmeier research home economist.

## ADDITIONS TO BUILDINGS AND EQUIPMENT

The permanent equipment of the stations was greatly improved during the year, especially in the matter of buildings and laboratories exclusively or partly for station use. Of the total income of the stations for the year, $1,273,993 was expended for equipment, the largest items of outlay for this purpose being buildings, $571,465; farm implements, $195,122; livestock, $138,330; apparatus, $166,311; library, $46,732; and miscellaneous, $156,033.

Some of the more important improvements in buildings and equipment were as follows:

At the University of Arizona a wool laboratory for use in animal husbandry work, and especially for studies of wool and mohair produced in Arizona in relation to quality, strength, shrinkage, and scouring, was completed, and a portion of the basement of the agricultural building was remodeled to provide additional space for the soil-physics laboratory.

A new agricultural building was dedicated at the University of Arkansas June 6, 1927. Under plans drawn by the department of agricultural engineering, the department of horticulture of the university had under construction a building on the station farm for packing fruits in which mechanical graders will be used and the various kinds of packs compared and studied. A farm of 160 acres, near Stuttgart, in the eastern part of the State and located in the center of the rice industry, was donated as the site of the new rice substation. The university now owns three farms on which substations are located, all donated by the respective communities, the others being one for cotton at Marianna and one for fruit and truck crops at Hope.

In California the agricultural engineering building at the branch college of agriculture and experiment station at Davis was completed, equipped, and occupied during the year. The budget of the university for the biennium 1927–29 carried an appropriation

of $300,000 for the construction and equipment of an animal science building, also to be located at Davis. The plans were drawn for this building, which will house the division of animal husbandry, including dairy production, animal genetics, animal physiology, and animal nutrition; the division of entomology and parasitology; and the division of zoology. A sewage-disposal system for the buildings at Davis, equipped with the latest type of Imhoff tanks and constructed at a cost of $50,000, was completed during the year. Arrangements were also made to open a rabbit experiment station at Fontana, about 50 miles from Los Angeles. The equipment will include 5 acres of land with an administration building, a caretaker's house, a feed storage shed, hutches, and other necessary buildings. This station will be established and operated under a cooperative agreement between the Bureau of Biological Survey of the United States Department of Agriculture, the National Rabbit Federation, and the Fontana Farms Co. The purpose of the station is to develop reliable information for rabbit breeders and raisers as to the best methods for breeding, feeding, and housing rabbits for the production of both meat and fur of high quality. It has been decided to locate at Berkeley one of the regional forest experiment stations authorized by Congress on March 3, 1924. This new station will give opportunity for close cooperation with the activities of the University of California along the lines of forestry instruction and research.

At the Colorado station a wooden building used to house the work in animal husbandry, dairy husbandry, veterinary science, and poultry husbandry was burned January 28, 1927.

The last legislature, among other appropriations, allotted to the Connecticut Storrs station $28,000 for a pathological laboratory and $19,920 for equipping the fruit-storage building.

The contract for the first unit of a new horticultural building for the college of agriculture and experiment station of the University of Florida was let and construction work was begun. For this unit a State appropriation of $125,000 is available. When the building is completed it will also house the agricultural extension service; the State plant board; and the library, the mailing room, and editorial offices of the station.

At Purdue University the new horticultural building costing approximately $150,000 was completed, and was dedicated November 11, 1926. This is a four-story brick structure containing 45 rooms and about 25,000 square feet of floor space. On the first three floors are classrooms, laboratories, and offices for the entire horticultural staff of the institution. Among the special features provided are a modern cold-storage plant with rooms available for storing at different temperatures, a spraying-machinery laboratory, a laboratory equipped for canning and preserving and the utilization of by-products, and various facilities for the use of the station. An allowance was made by the last legislature of $70,000 for a research unit of the agricultural engineering building, and of $25,000 for an addition to the poultry building.

Provision was made for four new buildings at Iowa college and station. A new dairy-manufactures building will be erected and equipped at a cost of $500,000, and $150,000 will be used for erecting a new feed-storage barn and horticultural crop-storage building, and a storage building for the agronomy section.

The Michigan college, on May 13, 1927, in connection with the celebration of its seventieth anniversary, dedicated the new Kedzie Chemical Laboratory, erected at a cost of $600,000. The appropriations made by the legislature toward the close of the year included $75,000 for a new dairy barn, $50,000 for farm-land purchases, $15,000 for drains, fences, and similar improvements, and $25,000 for a substation for experimental work with potatoes. A new horse barn 45 by 135 feet and costing about $20,000 was completed during the year.

The department of agriculture of the University of Minnesota began work during the year on a plant-industry building which, with equipment, is to cost $250,000. This buiding will house the division of agricultural biochemistry and will furnish much needed laboratory equipment for the entire plant-industry group. It will be a three-story structure of brick and limestone, 65 to 154 feet in size.

At the Mississippi station a laboratory and an office were fitted up for the station home-economics department hitherto located on the campus of the Mississippi State College for Women at Columbus. A new greenhouse was provided at a cost of about $5,000 for the departments of bacteriology, entomology, and plant pathology.

The nutrition laboratory for the study of basal metabolism with live-

stock at the New Hampshire station was enlarged to include a section to be devoted to work in human nutrition, in cooperation with the Nutrition Research Laboratory of the Carnegie Institution of Washington.

Under congressional act the New Mexico College of Agriculture was granted public lands aggregating about 55,000 acres for use in work with livestock, grazing methods, and range forage plants. The tract is located near Fort Selden, in Dona Ana County, and some lands, watering places, and fences on the area are already owned or controlled by the college or the experiment station. The acquisition of this entire area will permit of large-scale experiments in range management, including work with range sheep and goats, some of which is already in progress.

The legislature of New York authorized the trustees of Cornell University to contract for the foundations of the new plant-industry building at a cost of $100,000. The total cost of the building is estimated at $1,250,000. It is to provide accommodations for the departments of botany, plant pathology, pomology, floriculture, and plant breeding. A gift of $30,000 was made by the Charles Lathrop Pack Forestry Trust to Cornell University for the endowment of a research professorship in forest soils, and additional funds were given for development of advanced forest research.

At the North Carolina college and station a new building costing $250,000 and providing accommodations for the animal husbandry and horticultural departments was completed early in the year. The building was named for L. L. Polk, founder of The Progressive Farmer and one of the men who worked for the establishment of the present college. The building is a complete modern structure, fully equipped with laboratories for dairy and meat work.

At Ohio State University two new greenhouses—one a vegetable house 36 by 78 feet and the other a flower house 25 by 90 feet—were added to the equipment of the horticultural department. The new animal-husbandry building, a combined administration, teaching, and laboratory building, with a meat-cutting laboratory, was occupied during the year.

Plans were prepared and work was authorized for the construction, at the Oregon Agricultural College, of a three-story poultry building 54 by 126 feet, which is to accommodate the poultry and veterinary departments and to include a cold-storage plant and research laboratories. The first floor will contain an incubator room, a fattening, killing, and judging room, and a class laboratory. The second floor will be devoted partly to work on poultry diseases, for which the legislature made special provision, and the third floor will be used by the veterinary department.

The South Carolina station acquired about 800 acres of land near Columbia, in Richland County, for the Sand Hill substation. The soil of this tract is typical of a wide range of Sand Hill soil and extensive experiments will be conducted under the direction of the station. An agronomy laboratory at the agronomy experiment farm, providing room for offices, equipment, and storage, was completed, and a station greenhouse, equipped with an automatic heat regulator and temperature control to facilitate experiments on the influence of temperature on the germination, growth, and development of plants, was constructed. The Pendleton Farmer's Society, organized in 1815, deposited during the year many of its oldest and most valuable books in the college library.

At the Virginia Truck Experiment Station near Norfolk a sweet potato storage house of 1,000 bushels capacity was added to the equipment. This house is to be used for certain phases of sweet potato storage investigations which heretofore have been conducted in cooperation with private establishments.

## AN IMPORTANT ANNIVERSARY

The year marked the fiftieth anniversary of the establishment of the experiment station in North Carolina, the second in this country to be authorized and opened under legislative provision, and the first in the Southern States. Need of assistance for farmers and for the exercise of control over commercial fertilizers, which were increasing in kind and amount, were the primary motives leading to the new station. The act establishing it provided for a State Department of Agriculture with which the station was connected, both supported by license fees on fertilizers. They were located at the State University at Chapel Hill, which at that time was the designated beneficiary under the Morrill Act.

The movement for the provision of an experiment station had its origin in a meeting called by the president of the State University, K. P. Battle,

including representatives of leading agricultural interests in the State. The sentiment being favorable, steps were taken to present the matter to the legislature, with the result that the act of establishment was passed March 12, 1877, and the station opened April 19, 1877, with Albert R. Ledoux as director and chemist. The unusual expedition which this action marked showed the importance attached to this step and the confidence at that early day in the value of such an institution.

In the summer of 1881 the station was transferred to Raleigh and located in the buildings of the State Department of Agriculture. From its beginning until 1887 it was supported by that department through funds arising from taxes on fertilizers. With the passage of the Hatch Act it was reorganized, its control being transferred to the board of trustees of the North Carolina College of Agriculture and Mechanic Arts, which had been segregated from the State University. The station continued, however, to work in close collaboration with the Department of Agriculture, and later an arrangement was effected under which, through a joint committee from the trustees of the college and the board of agriculture, the experimental work of the two institutions was brought into close cooperation, considerable amounts of money and important facilities being supplied by the State Department of Agriculture.

More recently, with a clear differentiation of function, the station was recognized as primarily responsible for the research, and the State Department of Agriculture generously agreed to the setting over of a portion of its funds to the support of the station. It also continued to afford the latter the use of its system of test farms, which have enabled special work to be conducted in various sections of the State.

The history of the North Carolina station is interesting because of its origin and the unusual changes it has undergone. It is novel in the relationship it has had to the State Department of Agriculture, and in the fact that from its foundation its local funds have been derived from the resources of that department and not through direct appropriation from the State treasury.

The relationship has been a peculiarly advantageous one. In conjunction with the strong and aggressive character of that department a background has been built up of which any State might justly be proud. The long and useful career of this second oldest State station makes this anniversary worthy of note.

## INSULAR EXPERIMENT STATIONS

The experiment stations in Alaska, Hawaii, Porto Rico, Guam, and the Virgin Islands, maintained by direct appropriations to the Department of Agriculture for the purpose, continued their work without change of policy under the administrative supervision of Walter H. Evans, Chief of the Division of Insular Stations of the Office of Experiment Stations.

The appropriations for these stations were as follows: Alaska, $76,240; Hawaii, $54,940; Porto Rico, $56,460; Guam, $24,160; and Virgin Islands, $22,180, making a total of $233,980.

In providing for the maintenance and administration of these stations, Congress has followed a policy different from that governing in case of the State experiment stations, as defined in the Hatch, Adams, and Purnell Acts. A system of centralized control has been maintained, because it was believed that the Federal acts making appropriations for the State stations imposed conditions and restrictions which the various Territories and possessions could not economically and profitably comply with.

The Alaska stations are primarily concerned with the problem of establishing an agriculture adapted to the wide seasonal variations of that large Territory. In Hawaii and Porto Rico the problem is mainly one of diversification, supplementing the larger plantation operations. In Guam the station is endeavoring to restore an agriculture which had fallen into an unsatisfactory state. The station in the Virgin Islands is endeavoring to develop new lines of production to meet the requirements of changed economic conditions.

## PUBLICATION

Measured by the concrete evidence of their published output, the stations make a creditable showing, both as to the scientific value and the practical usefulness of their work. There has been steady improvement, both in form, range, and content of their publications. They deal with almost every phase of the varied agricultural problems of the country and represent distinct contributions to the scientific solution of many of them. The results of station work in printed form are

widely distributed and are having a distinct and far-reaching influence in improving farm practice.

The classified list of publications issued by the stations during the year in their regular series (see pages 97–113) contains titles of 743 publications. In addition, 21 stations contributed or collaborated in 77 articles published in the Journal of Agricultural Research, and a list, prepared with the cooperation of the stations, of technical or semitechnical articles reporting or based on results of station work, includes 1,375 articles in 303 journals.[3] This is significant of the large extent to which other channels of publication than the regular series of reports, bulletins, and circulars are being used. Such publication leads to a wider and better appreciation of the work of the stations and adds to the scientific prestige of the station investigators.

Special effort is made to obtain station and department publications, as well as those of similar institutions throughout the world, and to publish abstracts of them promptly in Experiment Station Record. This serves not only to bring together the results of the work of these institutions in compact and convenient form for the use of investigators, teachers, extension specialists, and others, but also to disseminate the information all over the world.

The total amount reported as expended by the experiment stations for publication during the year was $271,959.98, of which $226,601.80 represented State funds, $20,614.89 Hatch funds, and $24,743.29 Purnell funds.

## SOME RESULTS OF RECENT STATION WORK

Scientific investigations of the experiment stations are finding solutions of many practical problems of the farm and of farm life. The following summary selects for brief review a few examples of recent station work which have led to positive conclusions of practical value and application, excluding references to work which at the present stage of development is of interest only to the investigator.

These reviews have been prepared by members of the staff of Experiment Station Record as follows: W. H. Evans, plant physiology and plant diseases; H. C. Waterman, soils and fertilizers; H. M. Steece, field crops; J. W. Wellington, horticulture; W. A. Hooker, entomology and diseases of animals; G. Haines and H. W. Marston, animal production and dairying; Sybil L. Smith, foods and human nutrition; R. W. Trullinger, agricultural engineering; F. G. Harden, economics and sociology.

### PLANT PHYSIOLOGY

About 30 of the experiment stations are conducting investigations on plant nutrition and metabolism, light, temperature, and water relations, growth phenomena, tolerance to injurious agencies, plant relationships, adaptations, etc. Many of these studies are of a fundamental nature and when concluded they will add to our knowledge of plant life. Progress on a few lines of investigations reported during the year is noted below.

**Light relations.**—The Porto Rico station has apparently found an explanation for the failure of some varieties of onions to produce marketable bulbs in the Tropics where the length of day and night varies by only an hour or two during the seasons of the year. Some of the well-known varieties of northern climes, as Prizetaker and Yellow Globe Danvers, did not produce bulbs under a short-day illumination (11 hours daily), although grown for more than 240 days. Vigorous top growth was made, but the bulbs did not get beyond the spring-onion stage. White Bermuda onions produced bulbs only during the season of longest days.

The influence of the length of the period of daily illumination of plants on their chemical composition is strikingly shown by experiments reported by the Wisconsin station. Tomatoes, salvia, and other plants were grown under similar conditions except for the length of time they were exposed daily to light. Tomato plants exposed daily to six hours' illumination for three weeks were found to have accumulated excessive quantities of carbohydrates, probably through their limited use in the synthesis of nitrogenous compounds. The plants were weak and unfruitful. On the other hand, when grown for three weeks with 14 hours daily illumination, tomato plants were vigorous and fruitful and they showed decreased percentages of carbohydrates and increased nitrogenous compounds.

[3] Present limitations of space and printing funds make it inadvisable to include in this report lists of other than the regular station publications, but attention is called to the fact that all obtainable reports of station work, wherever published, are reviewed in Experiment Station Record.

**Plant nutrition.**—The proper balance between the various fertilizer elements for the maximum growth and yield of plants in cultures or in the field is still a matter of investigation at a number of the stations. Experiments at the Michigan station covering several years have shown that a rather wide range of salt ratios could be utilized by cereals without appreciable differences in yield, provided that all essential salts were available. However, it was found that different proportions of the fertilizer elements were utilized at different stages of growth. Experiments at the Kentucky station with tobacco in sand cultures failed to show any best fertilizer combination for the growth of that crop to maturity. Studies at the California station with peas, millet, etc., indicate that aluminum is an essential for plant growth. Experiments with silicon showed that in the absence of that element rice and millet were seriously attacked by fungi, whereas plants receiving silicon escaped injury. The Indiana station found that different lines of corn varied in their ability to take up iron and aluminum, and some hybrids absorbed less of these elements than the parent lines. The tendency of some hybrids to show dead or dying areas between the veins of the leaves seemed to be associated with relatively high percentages of iron and aluminum in the dry matter of the leaves. Experiments with soy beans at the New Jersey stations have shown that in culture solutions the iron content must be kept as low as possible without inducing chlorosis, due to a lack of assimilable iron. Concentrations in excess of the optimum were found to result in iron toxicity, and plants grown under such conditions had a high iron content in all their parts.

The Indiana station has described a method for recognizing deficiencies in soil nutrients that are considered essential for the normal growth of the corn plant. The method is based on color reactions of cut stalks to certain chemical reagents, and it is said to apply particularly to the nitrogen, phosphorus, and potash requirements. On the other hand, the Ohio station reports conflicting results with the tests when applied to corn plants grown on plats whose fertilizer treatments were definitely known.

**Growth relations.**—The transpiring rate of corn plants was found by the New Jersey stations to be an index to the rate of growth and the total dry weight of the plants. Similar results were obtained at the Kansas station, where transpiration and leaf area were found to increase steadily for about 80 days, or until the plants had attained full leaf development. After that period transpiration fell off rather abruptly, but the dry matter continued to increase to the end of the experiment.

The New Jersey stations investigated the effect of seed mutilation of oats and soy beans, and it was learned that the removal of a portion of the endosperm of the seed had the effect of retarding the early growth of the plants, but this was overcome later and there was no total effect on the height of the plants, growth, as measured by transpiration, or dry weight at maturity. At the same stations experiments showed that the chlorophyll content of corn leaves is more closely correlated with leaf area than with total weight of the leaves.

**Parasitism and resistance.**—Physiological studies are in progress on the nature of parasitism and reason why some plants are resistant while others are susceptible to diseases. The Wisconsin station found that for certain plant diseases soil temperatures profoundly influence the occurrence and severity of attack. By taking advantage of differences in the temperature requirements of the host plant for its optimum growth and the temperature for the fungus for its development, serious losses may be avoided. This relationship also explains why some diseases do not spread with the geographic distribution of the host plants.

Recent work at the California station is said to indicate that sour-orange bark contains a substance that prevents the growth of the fungi which cause gummosis and scaly bark of citrus trees, while lemon bark does not inhibit the organisms. This probably explains why sour-orange stock is resistant and lemon stock susceptible to gummosis and shedding of bark.

Studies of flax wilt at the North Dakota station revealed the presence in the cell sap of diseased and sound plants of two distinct globulins, protein compounds, one of which is associated with strains of flax that are resistant to wilt and the other with susceptible strains. The Minnesota station found that by growing the flax-wilt organism in saccharine culture media ethyl alcohol was produced, but there were marked differences in the amount of alcohol produced, the least virulent strains of the fungus producing the smallest percentages of alcohol.

The Ohio station, from a study of resistant and susceptible varieties of plants, concludes that variations in the hydrogen-ion concentration of the cell sap are not the causes of differences in resistance to disease. In one series of experiments tomato plants attacked by wilt had a more alkaline sap than sound plants, but this difference is believed to be due to the activity of the fungus and not of the host plant itself.

**Miscellaneous physiological studies.**—Experiments have been conducted at a number of stations on the effect of certain gases used for coloring and ripening fruit, blanching celery, etc. The Florida station reported on tests of a number of gas treatments for the rapid coloring of citrus fruits in which it was found that only ethylene and acetylene were satisfactory. All others gave an undesirable flavor to the fruit. The Pennsylvania station claims that ethylene gas, used for blanching celery, stimulates enzymes that are normally present in the stalks and leaves which break down various compounds resulting in the blanched product.

On account of the increasing use of arsenicals for the control of insect pests the effect of arsenic residues in the soil on plant growth was investigated by the Montana station. The transpiration, and hence the growth of tomato plants, was diminished when arsenic trioxide was added to the soil in the proportion of 10 parts per million. Severe injury and death of the plants followed increased applications of arsenic. The effect was much more pronounced with sandy soils than with humus soils. Beans and cucumbers were found to be quite sensitive to arsenic in the soil, but cereals and grasses were more tolerant. In general, the incorporation of considerable quantities of arsenic in soils was found to be a dangerous practice.

Investigations on the physiological, or June, drop of immature fruits have been in progress at the Delaware station for several years, and the results are believed to indicate a correlation between the time and mode of shedding and the genetic relations of the trees. Trees of the same strain shed their immature fruits in similar and parallel waves, and neither stocks, root diseases, nor application of fertilizers was able to change the time and manner of shedding. The apple variety, Jonathan, was found to shed its immature fruits in a simple compound wave with several minor crests, while Stayman Winesap sheds its fruit in a compound wave with about four major crests. Seasonal variations were noted in this behavior, but all varieties reacted similarly.

Contrary to the conclusions of the Wisconsin station that sugar beets store the largest amounts of sugar in the relatively cool, fair days of autumn, the Louisiana station reports that sugar beets can be successfully grown in that State by sowing the seed in October, the crop being harvested in May. There was an increase in sugar content with the warmer, longer days as the beets enlarged, 15.25 per cent sucrose having been obtained in a lot harvested early in May.

## SOILS AND FERTILIZERS

The large group of station projects in these two closely related fields has included investigations bearing upon a wide range of fundamentally important questions, and furnishing, in the aggregate, a very encouraging number of indications definitely applicable to the improvement of soil management and crop production.

**Permeability and alkali soil reclamation.**—Physical measures for black alkali soil reclamation were found effective at the Arizona station, where drying out and cultivating after leaching to the point of impermeability enabled "frozen-up" black alkali soils again to absorb water. Summer leaching precipitated their dissolved alumina in a form less impermeable than that resulting from the cold water used in winter leaching. At the New Mexico station the smaller heads of water brought about a less decrease in the penetration rate than did the larger. At the Idaho station leaching improved ammonification, which had been reduced by the chloride, carbonate, and sulphate of sodium, so that in many cases it became more than normal. Nitrification, reduced by the same salts, remained low after leaching, but could be increased by manure treatment. Nitrogen fixation was less affected by soil alkali salts.

Among chemical treatments which successfully reduced black alkali impermeability, in experiments at the New Mexico station, were applications of the sulphates of aluminum and iron, the improvement persisting under irrigation. Aluminum sulphate was the more effective. Aluminum chloride, potassium acid sulphate, ferric chloride, superphosphate (acid phosphate),

manure, and ammonium sulphate, in order of decreasing efficiency, were also found useful. The sulphide and sulphate appeared to be the only aluminum compounds having a neutralizing effect in black alkali soils, according to the Arizona station, however; although sulphuric acid increased the percolation rate when applied to the extent of 100 tons per acre. This improvement was greater than that obtained with gypsum. At the California and Idaho stations, also, sulphuric acid was found to be a more or less efficient corrective. The greater part of the alkalinity of the soils studied at the latter station was remediable by treatment with sulphur, field trials showing striking improvement in crop yields. Calcium carbonate was found to be a very desirable addition in the sulphur reclamation of alkaline soils. One ton of sulphur or 4 or 5 tons of gypsum per acre, together with light applications of manure, effected structural improvement in black alkali soils at the Oregon station.

**Exhausted and other infertile soils.**—An increase in water content above 45 per cent was found by the New Jersey stations to decrease the decomposition of the organic matter in a progressively unproductive cranberry bog. The long-time effect of liming showed some promise of the improvement of fairly dry, well-aerated peat. The Michigan station found buckwheat to be better than oats for increasing the decomposition of peat soil. Phosphate fertilization of peat soils at the Minnesota station increased the yields of straw by several hundred per cent, hays by from 20 to 50 per cent, and grains usually by as much as from 10 to 20 per cent. It was demonstrated that nitrogen was not the limiting factor, despite a carbon-nitrogen ratio of 20 : 1.

Nitrification was found by the North Carolina station to be active in highly acid muck soil and the denitrification of added nitrate was shown to be insufficient to deprive a growing crop of nitrogen. Stable manure increased carbon dioxide evolution, apparently without affecting other soil properties. Of the liming materials tested, ground dolomite appeared to cause the greatest acceleration of organic matter decomposition during the first two weeks, though this advantage later disappeared.

Diking and draining salt marsh land was shown by the New Jersey stations to result in the removal of so much of the salt by leaching that the salt grasses of value as hay were replaced by goldenrod and dog weed, and the condition of the marsh approached that of fresh-water swamp.

The productivity of certain coniferous timberland ("turpentine soils") was found by the Idaho station to be little affected by fertilizers other than nitrates. In experiments at the Washington station pine needles and sawdust depressed crop yields less when used as a source of organic matter for the soil than did straw. While both pine needles and sawdust showed a depressing effect when used alone, the addition of 150 pounds of sodium nitrate with 2 tons per acre of either pine needles or sawdust improved yields. Straw required a greater supplementary quantity of sodium nitrate for the correction of its depressing effect than did either the pine needles or the sawdust.

**Soil toxicity.**—The Arizona station found that the infertility of black alkali soils is ordinarily attributable to sodium chloride and sodium sulphate and to extremely unfavorable physical condition rather than to the usual content of actually alkaline compounds. Calcium, even in minute quantities, enormously increased the ability of plants to resist the effects of sodium chloride and other alkali soil salts.

Aluminum toxicity, according to the Rhode Island station, varies widely with the nature of the crop. Lettuce, beets, timothy, and barley were injured by as little as 2 parts per million of added aluminum; radishes, sorghum, cabbage, oats, and rye, by 7 or less parts per million; and corn, turnips, and redtop, by not less than 14 parts per million. Dwarfing and root injury were the first symptoms noted in aluminum poisoning.

**Soil acidity.**—The usual fertilizer applications, with the exception of ammonium sulphate, had little effect upon soil acidity, in experiments at the Ohio station, although superphosphate (acid phosphate), sodium nitrate, bone meal, basic slag, and manure all tended to reduce acidity slightly over a period of 11 years. Applications of 4 and 8 tons of limestone per acre every four years affected the subsoil reaction to a depth of 28 inches, while 2 tons per acre appreciably affected only the surface layers.

**Partial sterilization of soils.**—Steam treatment at 30 pounds pressure, which raised the temperature to about 203° F. in all parts of a greenhouse seed bed for from 3 to 3.5 hours, was shown by the Colorado station to be effective in destroying Fusarium infection and nematodes. Similar treatment, using a

steam pressure of 80 pounds applied through wooden pans on the surface, was also found effective for outdoor seed beds where only the surface soil to a depth of 4 to 6 inches needed to be sterilized. Ammonifying bacteria did not appear to be destroyed by the steam, but the nitrifying and nitrogen-fixing bacteria were killed. It is considered, therefore, that for three months after sterilization all fertilizer nitrogen used should be in readily available form. The Ohio station found differences of as much as 40° F. between points 6 inches apart and at the same depth in greenhouse soils which had been steamed for from one hour to three hours. The poorest steam penetration was that of wet clay soils, indicating the necessity of a thorough loosening of the soil, with a breaking up of all lumps, prior to attempting steam sterilization. In a heavy, wet clay soil, doubling the time of application of the steaming pan from 1.25 to 2.5 hours increased the depth of penetration by nearly 50 per cent. The harrow method proved much less effective than the pan method.

**Lime and liming.**—At the Connecticut Storrs station the effectiveness of limestone was found to depend on the fineness of grinding as well as upon the actual base content; and at the Ohio station grinding more than doubled the neutralizing power of granulated slag, although it showed only 61 per cent of the neutralizing efficiency of ground limestone. The Michigan station concluded, however, that over a period of some years the larger and more economical yields are secured, and the effects are more prolonged, by the use of the coarser grades of limestone. Extreme fineness in limestone was also found unnecessary by the Illinois station.

The smaller applications of lime in the form of either limestone or hydrated lime yielded nearly twice the crop obtainable from the heavier liming rates, in experiments at the Pennsylvania station. At the Illinois station, too, while the heaviest lime applications gave the largest actual increase in yield, lighter applications gave yields so nearly as good that the net return per acre was better than from the heavier applications.

Calcium carbonate, hydrated lime, dicalcium silicate, and a commercial mixture of monocalcium silicate and calcium oxide produced practically equal effects when applied in chemically equivalent quantities at the New Jersey stations. Dolomite and high-calcium limestone gave about equal results at the Illinois station, and similar conclusions were drawn by the Pennsylvania station with reference to pulverized limestone, hydrated lime, and ground and burnt lime. Hydrated lime appeared to be more effective in neutralizing acidity than ground limestone at the Connecticut Storrs station, although the difference lessened progressively after treatment. Freshly recovered marls were found by the Michigan station to be unsuitable for the liming of new alfalfa seedings.

A delayed effect of liming was observed by the Kentucky station, indicating the possibility that intervals up to two months between liming and the seeding of legumes may be necessary to obtain the full benefit of the treatment.

**Soil organic matter.**—The Colorado station found that leguminous crops not plowed under produced a soil improvement quite out of proportion to the very small nitrate accumulation induced by their growth. They increased the concentration of carbon dioxide in the soil atmosphere to such an extent as to bring about the solution of potash and phosphoric acid from the soil constituents. Wheat, oats, and grasses, although less active in this respect than the legumes, were found to be apparently much more effective than such crops as potatoes, beets, and corn. Nitrate production was reduced by the crops found effective in increasing the soil carbon dioxide concentration. The New Jersey stations showed that the depression of crop yields immediately following the incorporation of organic matter into the soil results solely from the absorption of soil nitrates by the bacteria decomposing the organic matter, the depressing effect continuing only until the decomposition has been completed and the nitrogen of the dead bacterial cells has had time to become ammonified and nitrified. The nitrogen was again available to crops after from four to eight weeks. Similar results with buried sugar-cane trash were observed by the Louisiana station.

**Green manures.**—At the Ohio station biennial white sweet clover, seeded with oats and plowed down the next spring for corn, produced gains more than double those obtained from medium red or mammoth clover. White sweet clover as a green manure gave greater yields of both corn and oats than did 8 tons of untreated manure. In experiments at the Kentucky station bluegrass following sweet clover gave a yield between two and three times as large as that obtained when

the bluegrass was grown continuously. The Illinois station found that the plowing under of sweet clover in the spring is better than fall plowing, and that summer plowing has no advantages with respect to nitrate production, and wastes a year. Soils deficient in organic matter or having a light, sandy, open texture benefited by as late a spring plowing in of the clover as was consistent with proper preparation of the soil for corn, whereas clays or loams and soils already cropped once or twice to sweet clover were found unlikely to be much affected with respect to corn production by the date of the spring plowing of the clover.

**Activated sludge.**—The Wisconsin station found that activated sludge satisfactorily replaced stable manure for a number of crops, for use as a top-dressing for golf courses and lawns, and in commercial greenhouse use, the sludge being weed free and requiring neither composting nor screening, and containing more phosphoric acid and nitrogen than does stable manure.

**Artificial manure.**—The New York State station found that a mixture of ammonium sulphate, superphosphate (acid phosphate), potassium chloride, and ground limestone, and commercial mixtures of similar composition were capable of rotting down straw, suitably wetted, in from three to four months. The practicability of the process was questioned, however, on account of the labor involved. Good manure was secured by the New Jersey and Louisiana stations using a commercial chemical mixture, although the expense was considered by the former to be a possible limiting factor.

**Nitrogen.**—The Maryland station found that the nitrification rate increased with increasing temperature up to about 68° to 86° F. in mixtures containing urea, ammonium sulphate, dried ground fish, or tankage. The optimum moisture content for the nitrification of these materials lay between 50 and 60 per cent of the water-holding capacity of sandy loam soil. Urea showed the highest nitrification rate at all temperatures; and at all except the lowest temperatures ammonium sulphate gave the largest final accumulation of nitrates. Drying to a moisture content below the hydroscopic coefficient was found by the Nebraska station to stimulate nitrification, the effect varying with the time up to at least eight months. The highest seasonal nitrification rate occurred in a cropped plat immediately after harvest and in a bare fallow plat in early October. The lowest rates observed were recorded after a period of sharp midwinter cold.

The nodule bacteria of alfalfa, peas, and sweet clover, once inoculated into eastern Washington semiarid soils, were found by the Washington station to persist uninjured by summer or winter extremes of temperature, and readily produced nodules after the absence for from 10 to 15 years of the host plant. Distribution of nodule-forming organisms by wind and dust storms was considered insufficient for the thorough inoculation of legumes planted in new fields.

Irrigation with continuous cropping to alfalfa brought about no significant difference in nitrogen accumulation in soil during the first two or three years, according to the New Mexico station. After six and seven years in alfalfa, removed as hay, however, the nitrogen and organic matter contents of the soil were found to have been markedly increased. This result was attributed largely to nitrogen fixation by root nodule bacteria.

**Phosphates.**—The Rhode Island station found the efficiency of floats to vary with a number of factors, including the nature of the crop, cabbages, rape, and rutabagas being especially capable of securing phosphorus from floats. Clover yields also were reported by the Minnesota station as having been quite as effectively increased by rock phosphate as by superphosphate (acid phosphate). Raw rock phosphate can compete with superphosphate under some conditions, according to the Maryland station, but superphosphate, whether applied alone or in combination with stable manure, was found to be usually the more economical.

Calcareous or alkaline soils failed to respond to applications of insoluble phosphates in experiments at the Arizona station, although they did respond to soluble phosphates. The Georgia station showed that while Florida soft-rock phosphate and Tennessee brown-rock phosphate gave about the same results, Tennessee blue-rock phosphate was inferior to both the others. The Illinois station found that rock phosphate gave much better responses when used with crop residues in a grain system of farming than when used as a supplement to stable manure.

The composting of rock phosphate with sulphur was found by the Geor-

gia station to cause no increase in the availability of the phosphoric acid. However, in the presence of certain activators, notably potassium sulphate, which strongly stimulated the oxidation of the sulphur, the Delaware station showed mixtures of insoluble phosphates with sulphur to give as good results in most cases as commercial phosphatic fertilizers.

**Potash.**—The New Jersey and Tennessee stations found the solubility of both native and applied potash in soils to be lessened by liming, with the prevention of the loss of a large amount of added potash. This difference was reflected in the potash content of cornstalks from limed and unlimed plats. According to the Ohio station, treatment of soils with calcium sulphate, ammonium sulphate, and sodium nitrate appeared to slightly increase the solubility of the soil potash in most cases. The Kentucky station demonstrated marked increases in water-soluble potash following sulphur treatment and some apparent increase from applications of gypsum.

Very little difference in fertilizer efficiency as between the sulphate and chloride of potassium could be detected by the Massachusetts station except in the treatment of cane fruits. These plants appeared to be subject to more serious winter injury when their potash supply was furnished in the form of the chloride. Potatoes also gave slightly greater yields when treated with potassium sulphate than when treated with potassium chloride. At the Indiana station, however, grain yields obtained by the use of the two forms of potash averaged the same.

**Sulphur.**—Both sulphur and gypsum treatments increased alfalfa yields in experiments at the Montana station, the former being the more effective. An increase in the protein content of the crop was also noted. Increases in the alfalfa crop due to sulphur or gypsum treatments were found insufficient to warrant the application of either, however, on the soils studied by the Colorado station.

**Auxiliary plant nutrients.**—Recovery from a characteristic chlorosis, induced in certain crops by liming the soil to neutrality, was secured at the Rhode Island station by sprinkling the soil with dilute solutions of the sulphate or chloride of manganese. Manganese sulphate in the fertilizer at the rate of 30 pounds per acre was beneficial, but sprinkling with a further 8-pound to 15-pound portion of manganese sulphate diluted with 1,000 parts of water was also needed. Thomas slag and extra quantities of superphosphate also proved helpful in the control of manganese-deficiency chlorosis. Oats, millet, beets, lettuce, and corn showed marked increases due to the addition of manganese salts, and onions were increased fivefold by this treatment. The addition of manganese salts also cured chlorosis of crop plants at the Kentucky station.

Boron in the form of borax was found by the Indiana station to be, when broadcast in very small quantities, distinctly beneficial to corn on two soil types and harmless on a third. Borax was found injurious when applied in the row with corn at a rate greater than that of 0.5 pound per acre; but it was harmful only in the early stages of growth and then only when applied near the seed and in dry weather.

A copper and arsenate mixture dusted on corn and cowpeas on freshly broken saw-grass peat was observed by the Florida station to be followed by good growth of the treated plants two weeks after treatment, at which time the untreated plants were dead. This difference was traced to the stimulating action of the copper in the insecticide. A very marked response to soil treatment with 30 pounds of copper sulphate per acre was subsequently secured. In tests on some 60 crop plants, in which a number of other special elements were tried, copper and manganese were found to be the most effective. Although zinc and nickel gave stimulating effects much earlier than did copper and manganese, this early stimulation did not last long enough to carry the plants through to maturity, and after the failure of the responses the plants had at times the appearance of actual injury. Copper, zinc, and boron, though required only in traces, appear, according to the results of experiments at the Kentucky station, to play some important part in the fruiting of buckwheat plants.

## FIELD CROPS

Field crops investigations at the experiment stations have shown a rather definite trend toward the more fundamental phases of research, although the practical application of the results has not been neglected. Efficient methods of production and the control of factors responsible for quality of products have been especially emphasized.

### CEREALS

**Improved varieties of smooth-awned barleys.**—The Minnesota station has found

it possible to obtain smooth-awned, white-seeded varieties of barley also resistant to *Helminthosporium sativum*, e. g., Velvet, Comfort, and Glabron, which appear to equal Manchuria in yielding ability, strength of straw, and resistance to *H. sativum*. Glabron seemed to be more desirable as to strength of straw than Manchuria (Minnesota 184), the currently recommended variety in Minnesota, being adapted, therefore, to rich lands.

**Drought resistant corn.**—Corn seedlings with medium green leaves appeared to be more resistant to drought than those having light or dark green leaves in experiments at the Porto Rico station.

**Moisture content of seed corn.**—The moisture in shelled corn was found by the Illinois station to be practically independent of temperature and to vary only with relative humidity, except when the latter was extremely low or high. Since a rise in temperature increases the moisture-absorbing capacity of the air, application of artificial heat, together with ventilation, is deemed advisable on cold winter days to maintain a low moisture content in corn in seed-corn storage houses.

**Method of applying fertilizers to corn.**—Germination and root growth of corn were retarded when fertilizers were applied in contact with the seed at the Iowa station. The desirable effects of fertilizers on the early growth, maturity, and yield appeared to be in proportion to the root development of the plant. Both primary and secondary roots made their maximum development when the fertilizers were applied in the hill and thoroughly mixed with the soil in an area extensive enough to avoid retardation of germination.

**Rice investigations.**—Yields in experiments at the Louisiana Rice station suggest seeding rice between May 18 and June 15, the use of from 60 to 80 pounds of seed drilled, and drilling instead of broadcasting. Rice on rotated plats made yields greatly in excess of those on plats continuously in rice. Confirming earlier results, the use of commercial fertilizer did not seem profitable in rice production on Crowley silt loam. In experiments at the Arkansas station rice made its best growth on an abandoned rice soil during the period up to May 15. From then until maturity a typical rice soil which had grown rice for several years excelled in crop growth and development. The poorest growth occurred on a virgin rice soil, which also matured the rice later than the other soils.

**Resistance of sorghums to chinch bug and smut.**—The Kansas station found that such sorghums as feterita, milo, Amber sorgo, and shallu were severely injured by chinch bug, while durra, kaoliang, Sumac sorgo, kafir, and the hybrids milo×kafir, hegari×milo, and Kansas Orange sorgo×milo, were distinctly resistant. Plants showing the most hybrid vigor apparently withstood chinch bug attack most successfully. With the exception of a few susceptible strains, feterita, Kansas Orange, Sumac, and hegari×milo were generally resistant to smut, whereas Dwarf Yellow milo, kafir, and some natural milo hybrids were generally susceptible.

**Hybrid vigor in sorghum.**—Marked hybrid vigor accompanied intervarietal crosses between milo and feterita at the Texas station in both $F_1$ and $F_2$ generations in height of plant, leaf size, chlorophyll development, and grain production, and the crosses were characterized by marked delay in maturity. Crosses between strains of the same variety either showed no hybrid vigor or else displayed it only in plant height.

**Wheat germination.**—Wheats germinated best at 10° and 15° C. at the Illinois station, and a moisture content of 50 per cent of saturation gave good results with all varieties studied. Wheat showed a wide adaptation to varying moisture conditions. The spring and winter sorts tested exhibited the same general reactions to varying temperature and moisture conditions as winter wheats.

**Irrigation of wheat.**—At the Colorado station wheat showed a higher production of protein for irrigation at the earlier growth periods, but best quality of protein and of wheat with irrigations at the heading and blossoming periods.

**Date of seeding winter wheat and winterkilling.**—In experiments at the Wisconsin station, the most resistant plants were developed by seeding in the last half of September. Late fall plantings suffered most from root fracturing and consequent drying out. Less winterkilling resulted on soil with a low moisture content. Very little fluctuation was apparent in the total nitrogen in the wheat plant during the fall and winter dormant season. While the soluble and protein nitrogen seemed to increase with a lowering of temperature, the protein nitrogen dropped rapidly after the freezing point of the plant.

**Factors influencing wheat quality.**—The Kansas station found that, in general, applications of nitrogenous fertilizers, except in the form of barnyard manure or cowpeas plowed under for green manure, slightly increased the protein content of wheat. The California station found that the peculiarities of loaf volume and percentage of protein of the different wheats corresponded rather generally with the varietal peculiarities in response to nitrogen applications at the various growth stages. The strength of flour of any variety of wheat seemed to be related to the protein content of the grain and to some factor or process connected with a period of development of the plants which is reflected in differences in time of ripening. The Nebraska station concludes that protein content of wheat shows a higher correlation with baking quality than does any other known chemical or physical factor or group of factors and continues to be the most important single chemical test. A survey among Nebraska millers showed that the protein content was considered the best evidence of baking quality of wheat at the time of purchase, although some favored the gluten test.

**Farm storage of wheat.**—The Kansas station found little danger of heating and damage to combine-wheat in farm storage if it is fully ripened when cut and if not wet by rain. Excess moisture due to immaturity of grain appears to be a more serious and frequent cause of damage by heating than is moisture from rain or dew. Unsatisfactory baking results appeared when over 5 per cent of bin-burned wheat was mixed with sound wheat.

### LEGUMES

**Seeding alfalfa.**—Alfalfa or sweet clover gave excellent results at the Wisconsin station when seeded with oats and the oats pastured off with cows. Late summer seedings could not withstand unfavorable winters unless covered with straw. The Michigan station found that when winter hardy alfalfa seed of high germination is sown on a well-firmed seed bed with a good drill the seeding rate within certain limits (4.7 to 24 pounds) does not influence the hay yield during the first four years.

**Inoculation of alfalfa.**—On land limed well in advance of seeding the Minnesota station observed that artificial cultures were as effective as a heavy application of soil from an established field of alfalfa or sweet clover, whereas on unlimed land the soil-transfer method greatly excelled in the case of the first seeding. The difference between the methods appeared to increase with the lime deficiency of the soil. Alfalfa sown after crops of alfalfa or sweet clover on such unlimed soils was satisfactorily inoculated.

**Cutting alfalfa.**—Alfalfa cut twice a year at the Wisconsin station at the full-bloom stage yielded better, as did the timothy in the alfalfa, than that in plats cut three times annually. Early and frequent cutting seemed to reduce the vigor of the alfalfa and pasture and hay grasses as well. Studies at the Illinois station indicated that hardiness alone did not suffice to insure a good alfalfa yield. Alfalfa cut in full bloom was killed out completely, while that cut in one-tenth bloom survived the winter in good shape. The Nebraska station concluded that harvesting alfalfa at about the new-growth stage should probably prove most desirable. With normal blooming conditions, this usually falls between the tenth and half-bloom stages. The Arkansas station observed that permitting alfalfa to remain before cutting as long as feasible without heavy loss of foliage was desirable for lasting stands.

**Winter hardiness in alfalfa.**—The Minnesota station found that resistance to cold seemed to increase in the roots of alfalfa plants as winter approached and to disappear with the coming of spring. A critical period was observed during early spring when the snow disappears and the soil thaws. The snow seemed to amply protect alfalfa plants against killing by low temperatures. Crown buds were evidently hardier than the root tissues just below them. There appears to be a transformation of starch into sugar during the late autumn and early winter and apparently a partial reconversion in early spring. Considering that sugar acts as a protective colloid, Grimm alfalfa appeared to have an advantage over Kansas-grown common because of its greater sugar content.

**Red clover seed.**—Using red clover from domestic and foreign sources the Virginia station showed that anthracnose infection is often less and the yields larger from fall than from spring seeding. Anthracnose appeared to be one of the chief reasons for death of spring-seeded clover during the following summer. The sources of red clover most resistant to anthracnose included Tennessee (disease-resistant), Virginia, Maryland, Ohio, and Michigan. If foreign-grown seed must be

used, seed from Chile, France, and north European countries seem best for Virginia conditions.

**Selections of soy beans for quality of oil.**—Selection for seven years within a soy-bean variety by the Wisconsin station resulted in a high and a low oil content with iodine numbers averaging 133.7 and 124.9, respectively. High quality of soy-bean oil seemed intimately correlated with a certain lateness of maturity. Selection for oil quality had no appreciable effect on the quantity or percentage of oil produced by the plant; no consistent correlation was found between iodine number and percentage of oil. Selection for high quality without decreasing the percentage of oil seemed possible, although this does not hold for large increases in the quality of soy-bean oil in any one variety by selection methods of breeding.

**Inoculation of soy beans.**—Increases in soy-bean yields obtained by the Illinois station as results of inoculation ranged from 5 per cent on fertile brown silt loam soils to more than 300 per cent on dune sand soil. Proper inoculation also materially increased the protein content of hay and seed. Pure cultures of legume bacteria were found superior to soil for inoculation. For best results seed should be planted within 24 hours after inoculation.

Soil broadcast at the rate of 500 pounds per acre resulted in the best inoculation at the Iowa station. The percentage of protein in inoculated soy beans increased with the degree of inoculation. The Ohio station found that quantities up to 400 pounds of mixed fertilizer or superphosphate applied below, above, or beside inoculated soy-bean seed did not affect germination and noticeably enhanced inoculation, particularly with the heavier applications.

**Cutting sweet clover.**—For maximum growth during the second year the Kentucky station found that the first year's sweet-clover crop, if made into hay should be cut not earlier than late summer or early fall. Cutting in midsummer of the first year appeared to reduce the second-year growth by one-third. The Ohio station found that cutting first-year sweet clover in the fall reduced the quantity of material stored in the roots, thus lessening the soil improving and pasture value of the crop the following season.

### FIBER AND OILSEED CROPS

**Delinting cottonseed.**—Cottonseed can be delinted by application of 1 part by volume of concentrated commercial sulphuric acid to 17 of seed in a method modified by the Tennessee station, saving about 60 per cent of acid as compared with the original method. Delinting may also be accomplished with acid diluted 1 part to 5 of water for 60 parts by volume of cottonseed, seed being delinted in about five days.

**Cotton fertilizers.**—Fertilizer experiments with cotton by the Mississippi station showed that Delta soils respond profitably to nitrogen only, although superphosphate should be used on those soils made directly from the hills. From 150 to 200 pounds of sodium nitrate or its equivalent in ammonium sulphate was indicated for average Delta soils, all of the fertilizer to be applied at or before planting.

The North Carolina station found that increases in the phosphorus in the cotton-fertilizer formula made for earliness, increases in nitrogen caused little or no change, and increases in potassium caused reduction in earliness on both Piedmont and coastal plain soils. Fertilized or not, more cotton was open at the first picking on sandy or sandy loam soils in the coastal plain than on clay or clay loam soils in the Piedmont.

**Spacing and thinning cotton.**—Close spacing and more plants per hill returned the larger yields in tests by the South Carolina station. The station recommends that cotton should be spaced to average about one stalk every 6 inches in the 4-foot row, providing for about 21,000 plants per acre. Late thinning at the Texas station resulted in cotton plants with fewer branches, particularly vegetative branches, and shorter branches, with first branches higher from the ground, and plants smaller in height and diameter, yielding later and yielding less than plants thinned at the usual time. Close and medium spacings, from 9 to 18 inches, made the earliest crop. The size of bolls generally rose as the distance between plants increased. No advantages appeared to be gained by late thinning.

**Undeveloped cotton fiber.**—The North Carolina station found the percentage of undeveloped fibers to be greatest at the rounded end of the cottonseed and evidently rising as the density of fiber population increased and also in the area of longer fibers. Continuous selection for high lint percentage should evidently be made with caution to avoid a concurrent increase of undeveloped fibers. The smallest percentage of undeveloped fibers was noted at the lower and inner bolls of the plant, whereas the percentage in-

creased in bolls toward the outer and upper portions of the plant, indicating the advisability of keeping separate the different pickings in order to obtain uniform samples.

**Storage of seed cotton.**—Storage of seed cotton from early October to late in February by the North Carolina station, in cooperation with the United States Department of Agriculture, did not change the weight, ash, or moisture content of the fibers, nor were the grade and staple influenced thereby. Breaking tests indicated a slight increase in strength due to storage, but when converted into yarn strength the increase was very small. The changes observed did not seem to warrant the expense and risk of storing seed cotton on the farm for the purpose of improving its quality.

**Flax retting.**—While addition of large quantities of pure cultures of efficient retting organisms to the solution hastened the retting process to a certain extent, in experiments at the Michigan station, the control of the acidity of the retting bath was found to be a more promising method. The acidity at which retting takes place seemed to have a pronounced influence on the quality of the flax, excessively acid or alkaline baths being conducive to harshness of fiber.

**Flaxseed and linseed oil.**—With flax harvested from August 25 to October 1 at the South Dakota station the weight per bushel and weight per 100 seeds increased consistently up to September 21, or complete maturity, whereas the average percentages of nitrogen and sucrose decreased with maturity. The average percentage of oil increased regularly from the first to the last cutting, but evidence was obtained that although early harvested seed would have a lower oil content, this oil would possess better drying qualities. The oil contents of nine varieties ranged from 33.9 to 37.4 per cent.

**Fiber production in hemp.**—Pistillate hemp (Cannabis) plants were found to produce a somewhat better fiber than staminate plants at the California station, probably because the latter mature more quickly, and medium sized plants produced a larger percentage of fiber than larger or smaller plants. Fiber quality deteriorated rapidly between the full-bloom period and full maturity, the deterioration being the faster in staminate plants.

**Fertilizers for hemp.**—The Wisconsin station observed that, regardless of the fertilizer application, hemp can not be satisfactorily grown on marshes until the excess of available nitrogen has been reduced. While marshes poor in available nitrogen have grown satisfactory hemp with commercial fertilizers, it is believed that most marsh soils will not produce a suitable quality of hemp fiber. Complete fertilizer has been most satisfactory on the mineral soils growing hemp. Barnyard manure has given good results and can be supplemented by commercial fertilizers under certain condition.

### POTATOES

**Induced germination of potatoes.**—In attempts to obtain immediate growth in freshly dug potatoes at the Arkansas station 100 per cent germination within 10 days resulted after treatment with the ethylene chlorohydrin method. This treatment should apparently be made below 70° F., although germination of the treated seed proceeds most rapidly at soil temperatures of about 80. Storing freshly dug tubers in a dry, airy place at 80° to 90° was also a promising method. Treatment of Early Ohio potatoes in a solution of ethylene chlorohydrin in water by the South Dakota station resulted in quicker germination and growth and more even stands than without treatment. Young tubers on treated vines were about twice as large as on untreated vines, and their size seemed closely correlated with vine development.

**Delayed planting of seed potatoes.**—Seed cut from the bud end of potatoes and planted at once by the New Hampshire station yielded 402 bushels per acre, and planted after eight days 324 bushels, while seed from stem ends gave 394 and 167 bushels, respectively. Sulphur was decidedly beneficial as a drier with seed held five days, but no advantage was noted with seed planted at once or after standing three days.

**Storage of potatoes.**—Storage experiments with potatoes at the Ohio station showed that ventilation may aid in lowering the temperature in the fall to the desired point but is unnecessary while storage temperatures remain below 40° F. Ventilation in the spring may aid in keeping the storage cool. Fresh air is essential when the temperature rises to the point where sprouting begins.

### SUGAR AND TOBACCO

**Production of sugar-beet seed.**—Sugar beets, fall planted, by the New Mexico station practically all produced seed stalks the following spring, as much as 3,000 pounds of seed per acre being

obtained with a possible average yield of 1,500 pounds. Comparative trials at several stations indicated that practically no difference exists between the quality and productivity of the New Mexico one-year seed and that of other commercial seed.

**Sugar-cane seed.**—The Hawaiian Sugar Planters station observed that normal flowering of sugar cane depends on high relative humidity, i. e., 80 to 90 per cent. While rainfall does not hinder flowering, pollen discharge is inhibited while the flowers are saturated with water. In self-fertile varieties opening of anthers could be retarded by frequent sprinkling during flower emergence, and it appeared possible to induce crossing of two strongly self-fertile cane varieties by this method. For the germination of sugar-cane pollen the optimum temperature appeared to be 22° C. at 96 per cent relative humidity.

**Improved sugar-cane seedlings.**—Seedling S. C. 22/21, a green sugar cane originated at the Virgin Islands station, resembled its parent, S. C. 12/4, ranked high in content and acre yields of sucrose at the Virgin Islands station, and is drought resistant, early maturing, and hardy. In germinating seedlings the greatest success followed planting seed from arrows collected from December 24 to January 7.

**Tobacco varieties.**—Brown, Crafts, Duncan, and Peckham have been outstanding in comparisons of Habana seed strains by the Connecticut Tobacco substation, indicating that certain strains in the Habana seed type are inherently better than others and that this superiority may be depended on to remain relatively constant under varying conditions of culture, weather, and soil. Jamaica and Yellow Pryor varieties, followed by Cash, have given the best acre returns in tests by the Georgia Coastal Plain station on a heavy phase of Norfolk sandy loam. Yield and quality were considerably increased by properly topping and suckering.

**Tobacco fertilizers.**—Experiments with bright tobacco by the Georgia Coastal Plain station, cooperating with the Georgia College of Agriculture and the United States Department of Agriculture, have suggested the use of 1,000 pounds per acre of an 8–3–5 (P–N–K) fertilizer. The phosphorus should come from superphosphate (acid phosphate), one-half the nitrogen from sodium nitrate alone or with ammonium sulphate and the other half from organic sources, and the potassium from potassium sulphate or a mixture of the sulphate with high-grade potassium chloride, the chloride supplying not more than one-half of the potassium. From 2 to 4 tons of well-rotted horse manure applied in the drill in addition to the mixed fertilizer is recommended. The Connecticut Tobacco substation found sodium nitrate preferable to ammonium sulphate to supply one-fifth of the nitrogen in the tobacco fertilizer formula. Dry-ground fish depressed burning quality somewhat, whereas tankage seemed as good as sodium nitrate and could replace cottonseed meal when the latter is high in cost. On fields not troubled with sand drown there seemed no advantage and indeed certain disadvantages in the use of potassium-magnesium sulphate nstead of potassium sulphate. Substitution of potassium chloride for a combination of potassium sulphate and carbonate did not affect the yield, although there was a material lowering of the grade index, and potassium evidently had a very serious effect in curtailing fire-holding capacity. The use of potassium chloride appeared inadvisable either for tobacco or for crops preceding tobacco. The Massachusetts station demonstrated the ready assimilation of urea nitrogen in the unchanged form by Habana tobacco. Plant growth, however, was not as rapid with urea as a nitrogen source as with sodium or calcium nitrate.

### CROP MIXTURES

**Soy beans and cowpeas with corn.**—Both soy beans and cowpeas materially reduced the average yields of corn when planted in corn at the Tennessee station, but the soy-bean yield nearly offset the decrease in corn, and the data seemed to favor soy beans in the mixture. The cowpea crop from broadcasting at the last cultivation of corn seemed uncertain but not detrimental to the corn yield. The Wisconsin station found that little seemed to be gained by planting soy beans in corn where soil and climatic conditions were optimum for corn. If conditions favored soy beans but not corn, the combination outyielded corn alone. When conditions favored corn the soy beans made an early rapid growth, although as soon as the corn shaded them they tended to become slender and to lose their lower leaves in dry seasons. On fertile soil in warm summers with plentiful rainfall throughout the growing season the combination produced more silage but less ears.

**Sunflowers and corn for silage.**—In tests of mixtures of corn and sunflowers at the New York Cornell station the grain percentage in the corn decidedly decreased as the sunflower percentage in the mixture rose, being of slight significance when as much as 50 per cent of sunflower plants was in the mixture. Mixtures generally outyielded an equal area grown half to corn and half to sunflowers. While the results did not favor sunflowers for silage in areas well suited for corn production, they indicated that this crop may be very useful on areas where late spring frosts and early fall frost make corn uncertain for silage, where very limited areas of highly productive land are available for crops and where a smother crop is wanted to aid in controlling grass and weeds.

**Flax-cereal mixtures.**—Extensive studies at the Wisconsin station demonstrated that while flax can be grown with any small grain, wheat is most satisfactory and oats reasonably so, whereas barley usually matures too early for the flax. About equal quantities by weight of flax and wheat or oats gave best results, whereas the flax-barley seed mixture should be about one and two thirds, respectively, by weight. On weed-free soil flax did better than a flax-cereal mixture, but with weedy land flax-wheat mixtures seemed to excel. Flax and small grains grown together yielded about the same as when the different crops were grown alone. Flax-oats and flax-barley mixtures were not satisfactory from the viewpoint of feeding. On irrigated land flax and wheat grown together in proper proportions by the Montana station gave total yields significantly larger than those from either crop seeded alone. Flax and Marquis wheat mixed at the rates of 14 and 30 pounds, respectively, and also at 14 and 45 pounds per acre, produced the most economical returns, yields averaging over 25 per cent more than from either crop in pure culture. There appeared to be no advantage in seeding such mixtures on nonirrigated land, where moisture is a limiting factor in crop production.

## FORAGE AND PASTURES

**Effect of altitude, season, and shade on forage plants.**—The Wyoming station observed that western forage plants increase in feeding value with rise in the altitude at which they are grown. The forage plants studied were generally less valuable for hay when cut unduly late in the season. The introduced grasses, timothy and redtop, suffered the most rapid loss in feeding value as the season advanced, while native sorts, such as wire grass and *Carex* spp., suffered least in feeding value from late cutting.

**Pasture and meadow mixtures.**—The Maryland station found that orchard grass, tall meadow oat grass, red fescue, and sweet vernal were satisfactory for pastures on hilly land, with the further addition of white clover and lespedeza for the slopes and mountain valleys. Kentucky bluegrass and orchard grass proved best for pastures at the station. For hay a combination of alsike clover, alfalfa, and timothy seemed much more profitable for yield and quality than clover and timothy grown alone.

**Permanent pastures.**—A mixed sod originally in good condition and subjected to grazing was successfully maintained by the Washington station by alternate grazing, close grazing, and heavy stocking. Further treatment, including manure and superphosphate top-dressing, scarifying, and reseeding, which continued to produce marked improvement in the grass yield, was the most promising improvement method tested. Scarifying with a spike-tooth harrow successfully controlled moss.

**Improvement of pastures.**—In pasture experiments by the New York Cornell station on depleted, generally unproductive, and high-grade pasture areas, superphosphate gave striking increases, whereas sodium nitrate or potash seemed of doubtful merit. Lime resulted in decided improvement in production and quality on the poorer areas, but not where desirable vegetation was already established. Manure, used only on the depleted pasture, nearly doubled the yield and resulted in an improvement of the vegetation quality by stimulating the white clover. Plowing and cultivation of old pastures were not of distinct advantage in these trials, nor could reseeding be recommended as a means of renovating old pastures. Cutting trials showed that well-established pasture areas will usually produce more green weight and almost as certainly less dry weight when cut often as pasture than when cut once a season as hay.

## WEEDS

**Bindweed control.**—No consistent decrease in the number of bindweeds resulted at the Kansas station from any of several chemical treatments compared with hoed fallow, except on

plats sprayed with sodium chlorate solution. Cultural tests suggested starting work with fallow in April and May, since spring-plowed fallow encourages more rapid growth of the weed. Sorghum smother crops succeeded best when sown about July 1 after an intensive fallow period. Effective eradication appeared to have resulted from 8 tons or more of salt without mulching or watering. Under somewhat moister soil conditions all rates below 20 tons of salt were ineffective. The Washington station found that from 40 to 45 cultivations with the weeder knife set 3 to 5 inches deep were required during the growing season to suppress bindweed. After two years of such cultivation about nine-tenths of the original infested area was free from the weed.

**Canada-thistle eradication.**—Solutions of chemicals were sprayed in November after frost had killed the tops of vegetation on permanent grass plats at the New York Cornell station among the weeds of which Canada thistle dominated. Observations during the next spring showed that the heaviest fall applications of sodium chlorate completely eradicated thistle, and that a rather small quantity sufficed to decidedly diminish their number and vitality. Potassium chlorate was similar in effects, whereas sodium arsenite was far less effective. Grasses and several other plants suffered little or no injury. The annual weed growth on the plats indicated that the poisonous action was of short duration. Calcium arsenite was the most efficient of five herbicides applied to Canada thistle by the Ohio station. It might be used satisfactorily when other control measures are not feasible, although chemicals did not appear economical for large infestations.

**Control of field mustard.**—Experiments at the New York Cornell station showed that solutions of sulphuric acid, 1 and 2 per cent, killed mustard plants under all humidity conditions, although best results were had in dry air. Iron sulphate solutions, on the contrary, were most destructive at about 100 per cent relative humidity. Iron sulphate acted much slower than the acid and was more effective at a lower temperature (6° C.), whereas the acid killed mustard the soonest at the higher temperature (30° C.).

**Small ragweed.**—The Iowa station observed that bluegrass pastures lost 50 per cent of their forage value because of the presence of small ragweed, which is destructive during August and September. It was easily destroyed by spraying during July with iron sulphate at the rate of 100 pounds to a barrel of water.

### HORTICULTURE

Progress was reported in many lines of horticultural investigation during the year, especially in the employment of physiological research to explain the growth and reproduction of horticultural plants.

**Reproduction and vegetative growth.**—A rather remarkable influence of fruit production on vegetative growth was observed in studies at the Missouri station with tomato plants, some of which were deflorated before actually flowering and others allowed to fruit in a normal way. The fruitless plants made greater height growth and, as measured by the dry weight of leaves, nearly double the total weight of foliage of normal plants.

**Fruit breeding.**—The New York State station, reporting on the results of 18 years of plum breeding, stated that high quality in the parents was found a requisite to high quality in the seedlings. In no instance were large-fruited seedlings obtained from small-fruited parents. Yellow color behaved as a recessive to red, purple, and black. The European species, *Prunus domestica* and *P. insititia*, were for the most part self- and intercompatible. No success met attempts to cross plums with peaches and apricots. Peach improvement continued to be an important feature of the work of the New Jersey stations. Several promising seedlings were propagated and named during the year, and favorable reports were received on those previous y disseminated.

**Pollen sterility in fruits.**—That germinability of the pollen of European grapes may be greatly influenced by the degree of pruning of the vine was shown in investigations at the California station. In 12 of 17 instances severe pruning, as compared with normal pruning, brought about marked reductions in pollen germination. On the other hand, very light pruning in one case increased germination to 606 per cent of that of normally pruned vines. Of many varieties of apples tested at the California station for self-fruitfulness, only three, Yellow Newtown, Esopus, and Baldwin, were found capable of producing crops with their own pol en. Gravenstein proved not only incapable of self-pollination but was also unsatisfactory for pollinating any other variety. In addition to the J. H. Hale peach, previously established,

pollen sterility was observed at the New Jersey stations in Chinese Cling and in various peach seedlings and to a partial extent in Late Crawford, Elberta, Belle, St. John, and Early Crawford varieties. The anthers of pollen-sterile flowers were notably pale in color and upon examination were found filled with a shrunken, broken-down mass of tissue. Of 127 seedlings resulting from the open pollination of J. H. Hale, 33 per cent were found pollen-sterile, as indicated by the abnormal color of the anthers.

Pollen sterility has been found by the Ohio station to be very prevalent in the varieties of apples grown in the State. Only three, Baldwin, Delicious, and Grimes Golden, were found capable, under controlled experimental conditions, of setting fruit from self-pollinated blooms. A positive correlation was observed between pollinating ability and pollen germination, the effective pollinizers having high percentages of germination and long tube growth Desirable and undesirable varietal combinations were determined, with no definite cases of physiological incompatibility being noted. Evidence was secured to suggest that wind is not a carrier of apple pollen. The need of caution in assigning poor fruit setting to inadequate pollination was shown in observations made by the New York Cornell station. In one instance a mixed Rhode Island Greening and Wealthy orchard, fruit setting in the Rhode Island variety was not stimulated by the introduction of blossoming branches of several varieties and of bees, except in the case of a few trees which had been severely pruned. Studies at the Illinois station with a number of species and varieties of gooseberries indicated that this fruit is predominantly self-fertile. That the Delicious apple is characterized by almost complete self-sterility and strong interfertility was evident from studies at the Maryland station, in which pollen of 14 varieties was applied to the flowers of a single Delicious tree. The Maryland results were corroborated at the Utah station, where the Delicious apple was found completely self-sterile, even when pollen was artificially applied from the same or from other trees. Jonathan proved to be a satisfactory pollinizer for Delicious. Pollen of tested germinability taken from different Black Tartarian cherry trees and applied to the emasculated pistils of a single Napoleon tree gave such variable results at the California station that it was concluded that there must exist outwardly indistinguishable types or strains of the Black Tartarian of different pollinating capacities, making it necessary to propagate from individual trees of known behavior.

That imperfect pollination in the apple may not always be a question of pollen sterility or incompatibility but may lie in the female portion of the flower was indicated in studies at the Ohio station. Irrespective of the variety and the amount of pollen and of the condition of the tree, in certain varieties a large proportion of the lateral blooms and in some cases of the central blooms in clusters failed to set. As a practical deduction it is suggested that varieties displaying this abnormal condition should be kept growing vigorously, should be provided with the right kinds of pollen and with sufficient bees to insure pollination.

**Wind and movement of pollen.**—Pecan pollen was collected at the Georgia station in adequate quantities to insure successful pollination approximately 1,000 feet from its source, showing that wind is an important factor in pecan pollination. On bright days pollen was collected in the air until after sundown, but in heavy, dull weather wind dissemination almost completely ceased. Wind is not a factor in the distribution of apple pollen according to the Ohio station. The New York Cornell station, however, suggests that very strong winds may influence apple pollination, but the Utah station concludes that severe winds are not only of no benefit but may be quite harmful by excluding useful insects.

**Oil sprays and transpiration.**—Reductions equaling 75 per cent in certain cases in the transpiration rate were recorded at the Illinois station in the case of apple, pear, peach, plum, and cherry foliage, the under sides of which were coated with oil sprays.

**Hardiness of apples.**—Comparisons at the Minnesota station of injuries induced to the terminal growth of apples by exposure to low temperatures produced artificially with the known behavior of the same varieties in the orchard showed a close correlation. Varieties of established hardiness were invariably located in the resistant groups and tender varieties in the susceptible groups. Long exposure at low temperatures was much more injurious than short exposure. Drying was not an important factor in injury, since cut twigs left outside for 2.5 months opened their buds readily in the greenhouse despite the excessive water loss.

**Propagation of fruit trees.**—Field observations at the Citrus Experiment Station, California, upon various orange, lemon, and grapefruit trees led to the conclusion that the character of the union of the stock and scion is a good index to the degree of congeniality and incidentally to the closeness of the genetic relationship between the two parts. Studies at the Wisconsin station upon the influence upon growth and survival of the position of the top bud of the apple scion in relation to the graft union bore out earlier conclusions, namely, that the bud should be directly above the matched side of the tongue. However, the California station, working on the same problem with pears and apples, failed to find any indication that the position of the apical bud had any significance, nor was any evidence secured to suggest that either the crown, middle, or basal portion of the seedling was significantly superior for propagation.

In studies of the influence of the scion when budded directly on the roots upon the character of the root growth in nursery apple trees, the Wisconsin station found that in almost all cases the scion, quite apart from soil effects, exerted a well defined influence upon the root system, in the proportion of fibrous to coarse roots, the size and direction of the roots, etc. In the case of double-worked trees, the root character was typical of the variety holding the intermediate position, leading to the suggestion that double working may be employed advantageously to secure uniform rootstocks for experimental plantings. Mazzard roots showed up to such advantage in comparison with Mahaleb roots in cherry plantings at the New York State station that the former are recommended as beyond question the better stock for sweet, sour, and Duke cherries. Identification of roots of mature citrus trees is deemed possible as a result of anatomical studies with various species at the California station. The high offshoots of the date palm were successfully rooted at the Arizona station by surrounding the basal portion with moist soil contained in a box supported by the necessary framework. At the California station a definite correlation was established between the degree of staining of freshly cut ends and the rooting ability of Sultanina grape cuttings dipped in a solution of iodine in potassium iodide. Starch determinations checked with the iodine test. Time of planting tests showed the desirability of early planting. Rooting was stimulated by immersion in solutions of various chemicals, especially oxidizing agents, such as manganese sulphate.

**Fruit storage.**—Investigations at the Pennsylvania station suggested that it is possible by too thorough draining to promote conditions in bank cellars too dry for successful apple storage. It is believed that the earth floor staying dry all winter absorbs a large quantity of moisture. A close relation between time of harvesting and behavior in storage was noted at the Oregon station for Beurre Bosc pears. Fruits harvested at the proper season kept well at 32° F. for 120 days and developed good quality when afterripened at temperatures between 60° and 70°. Wilting was prevented by wrapping the individual pears and holding in a relative humidity of 70–80 per cent.

**Girdling apple trees.**—Extended studies at the Ohio station and in Ohio commercial orchards demonstrated that girdling may be successfully resorted to as a means of inducing fruiting in tardy filler apple trees. Girdling was accomplished by drawing a knife blade completely around the limbs in late May or early June, and in vigorous trees produced no ill effects and promoted abundant fruit bud formation on the treated limbs. At the Utah station girdling was more effective than other treatments in inducing flower bud formation in the Delicious apple.

**The effect of shade on apple trees.**—The disastrous effect of continued shading on fruit bud formation and on general vegetative vigor was shown in studies at the Maryland station, in which young bearing Stayman Winesap and Grimes Golden trees were shaded entirely or in part with muslin. Shading for two consecutive seasons resulted in the inhibition of fruit bud formation and in a weak, slender growth highly susceptible to winter injury. In the case of half-shaded trees no transfer of carbohydrates was found from the exposed to the shaded part of the tree.

**Soil moisture in apple production.**—That soil moisture is a more critical factor in midwestern than in eastern apple orchards was suggested by observations at the Illinois and New York Cornell stations. At the Illinois station it was found that the moisture content of the 3–6-inch soil layer may vary as much as 10 per cent around a single tree, while at the New York station a Jonathan tree isolated by trenches and with the soil covered with waterproof paper failed to suffer dur-

ing an entire growing season any apparent injury to either growth or fruit. At the New York State station correlations between the yield of Rome Beauty apple trees over a 15-year period with temperature and rainfall suggested very strongly that moisture during midsummer had a very direct bearing on production, while during the same period temperature departures from the normal had no such marked effect.

**Fruit thinning.**—The size, color, and percentage of uniform, perfect fruits were materially increased by thinning in case of 12-year-old Stayman Winesap apple trees growing at the Maryland station. A spacing of 6 to 8 inches gave the best results. Distinct varietal responses to thinning were evident in peaches; Greensboro, for example, reacted more favorably to severe thinning in a dry season than did Elberta. Favorable results in thinning peaches and apples were also secured at the New Jersey stations.

The results of studies on the seasonal development of peach pits at the Illinois station suggested that too much stress has been laid on the need of early thinning to avoid the drain of seed formation on the tree. In actual thinning tests there was observed a relatively wide range in the time for thinning as measured in the size of the remaining fruits at maturity. Pruning and fertilizing were found to have an important bearing on thinning practices.

**Grades in different varieties of apples.**—Very marked differences were found by the Michigan station in the proportion of A-grade apples in different varieties. Based on four years' records of 10 important kinds, the range was from 38 per cent of A-grade fruits in Baldwin to 76.3 per cent in McIntosh. The factors promoting cull fruits also differed according to variety; for example, small-size, limb-rub, and handling bruises were the critical factors for the Baldwin, Rhode Island Greening, and Northern Spy, respectively. Arranged in descending order according to average market value of A-grade fruit, were Delicious, Yellow Transparent, Sweet Bough, Jonathan, Northern Spy, Red Canada, McIntosh, etc. Various indirect factors, such as the location of the orchard, the nature of the soil, and the character of the personal management, governed largely the success or failure in apple production.

**Fig pruning.**—The California station observed that the removal in early spring of the terminal buds of the White Adriatic variety of figs caused the fruit buds which normally form abundantly but drop off to cling and to develop into clusters of large edible figs. On other varieties—Dauphine, Madeleine, etc.—pruning had no such effect.

**Citrus studies.**—Root growth in grapefruit, sour orange, and sweet orange seedlings was found by the California station to have rather well-defined temperature requirements. Aeration favored both root elongation and root-hair development. Under favorable temperature conditions sour orange roots in sand were inhibited in development 1.2 to 1.5 per cent as a minimum. A concentration of the carbon dioxide in the soil atmosphere proved, even in the presence of abundant oxygen, to be a hindrance to root development. Checking field observations, in which it was noted that during periods of excessive heat small-sized oranges drop much more quickly than do the larger sizes, it was found in the laboratory that in young oranges and grapefruits the percentage loss of moisture decreased rapidly as the fruits gained in size. Observations made in an orange orchard four years after differential fertilizer treatments had been discontinued showed important hold-over effects; for example, nitrate of soda, usually thought of as a temporary fertilizer, was still very effective.

**Differentiation in pecan buds.**—Microscopic examinations at the Oklahoma station failed to show any indications of differentiation of pistillate flowers in the pecan until after growth had commenced in the spring. Fruiting branches did not as a rule originate from any lateral buds which were more than 2 inches from the terminal bud. The rate of development of the pistillate flowers was much slower than that of leaves on the same shoot.

**Fertilizing cherries.**—Of various nutrient materials applied by the New York State station to sour cherry trees growing in the Hudson River Valley, only those containing nitrogen had any material effect on growth and yield. Pruning when accompanied by nitrogen fertilization gave good results.

**Pruning the Concord grape.**—Under good cultural conditions it was found possible at the Maryland station to complete the framework of young Concord grapevines by the end of the second season in the vineyard. Severe pruning decreased root growth of the subsequent year.

**Growth and yield in the grape.**—The previously established relationship between growth and yield of the subsequent year in the Concord grape was found at the Michigan station to continue to further crops. The coefficients of correlation between pruning weights and the crop were for a sandy soil vineyard 0.75±0.02, 0.73±0.03, 0.37±0.05, and 0.68±0 03 for the four years following pruning, and for a vineyard on a heavy loam soil 0.58±0.3, 0.43±0.04, and 0.40±0.04 for the three years succeeding pruning, suggesting the possibility of using growth measurements as a means of selecting experimental plats, particularly in fairly uniform vineyards.

**Primary grape shoots the best.**—Records taken at the Arkansas station following a late freeze which destroyed many of the primary shoots of Concord grapes showed beyond question that the primary shoots are significantly more productive than those arising later.

**Bramble studies.**—At the Missouri station a close correlation was established between the amount of winter injury in blackberries and the percentage of freezable water in the bark. Cover crops increased hardiness, apparently by utilizing some of the available soil moisture. In raspberries the least injury was recorded in the plants having the highest percentage of bound water. At the Michigan station a survey of various commercial raspberry plantations showed the importance of proper location in respect to the character of the soil and of air drainage in securing regular, profitable yields.

**Tolerance to soil acidity by the strawberry.**—A wide range of tolerance on the part of the strawberry to acidity in the soil was found by the Michigan station. In water cultures strawberries made the best growth and the largest average weight gains in a pH 5.7 solution, but did not suffer within the limits of pH 3 and pH 8. On muck soils so acid in reaction that even acid-tolerant plants were apparently excluded, strawberries were benefited by moderate lime applications.

**Stable manure for the strawberry.**—Stable manure was found at the New Hampshire station to be especially beneficial in respect to the survival of strawberry plants and their subsequent growth measured in the number of new runners. Chemical fertilizers, on the other hand, especially when used alone, had a reducing effect on plant survival and upon vegetative growth.

**Pollination studies with melons.**—In melon-hybridization studies at the California station, little evidence was found that pollen had any immediate effect on the flesh color, skin color, ribbing, netting, flavor, and aroma. Time of ripening and shape of the fruits were apparently unaffected, but there was some indication that fruits from crossing were heavier than those from selfing. In some instances the number of seeds per fruit were significantly higher in crosses, but no difference was observed in the average weight of the individual seeds.

**Cultivation of vegetables.**—Evidence was secured at the New York Cornell station, in long-continued studies, that the principal benefit of cultivating vegetables is not in water conservation but in the control of weeds. In three plants—carrots, cabbage, and tomatoes—cultivation failed to increase yields above those secured by simply scraping the surface, and with the exception of celery scraping gave better results in some years. No significant differences were found in the nitrate nitrogen content of the soil due to the kind of tillage, but in 12 out of 17 determinations a positive relation was noted between moisture content and the quantity of nitrates.

**Fertilizers for vegetables.**—A report on long-continued fertilizer studies at the Pennsylvania station, in which a rotation of early cabbage, early potatoes, tomatoes, and wheat is practiced, indicates that phosphorus is the outstanding limiting factor on the soil utilized. Relatively small amounts of nitrogen and potash were required to maintain full production; in fact, in certain cases large applications of potash frequently resulted in losses. Superphosphate was the most satisfactory carrier of phosphorus. Continuing the study of the effect of phosphorus on vegetables, the New Hampshire station found a markedly beneficial effect of phosphorus in superphosphate upon the early growth of Hubbard squash and Danish Ball Head cabbage. Potash in the form of muriates decreased yields. Attempts at the Texas station to improve the keeping and carrying qualities of tomatoes by the use of potash fertilizers gave negative results. Potash did, however, increase yields and also the percentage composition of potash in the fruits and plants. Studies at the Ohio and Illinois stations gave evidence that greenhouse crops may be effectively produced with less animal manure than is commonly utilized if part of the manure is replaced with commercial materials. Superphosphate (acid phosphate) apparently decreased the yields of lettuce at the Illinois station, but this

effect was offset by liming the soil. At the Ohio station no deleterious effect of lime on lettuce was observed until a pH value of 8.5 was reached, suggesting that lettuce is quite tolerant to alkaline soils. Cylinder and field experiments at the Virginia Truck station established the fact that the soil reaction range for the optimum growth of spinach is rather limited. Acid injury was manifested in low percentage of germination, yellowing and burning of the seedling leaves, browning of the roots, and death of many of the plants. Neutralizing acidity with lime required caution, as heavy applications resulted in alkalinity, which in turn induced an unhealthy chlorotic condition, especially in the spring crop, and applications of manganous sulphate only reduced this condition in the early stages of the trouble.

**Ripening and storage of tomatoes.**—Propylene was found at the California station to be a more effective agent for hastening coloring in tomatoes than was ethylene. A temperature of 77° F. proved most favorable for forcing. At this temperature the maximum sugar content was reached in about four days in fruits harvested when partially colored. For general storage of tomatoes a temperature range of 54 to 59° F. was found most satisfactory. Observations at the Indiana station upon the keeping of tomatoes harvested when fully ripe indicated the advisability of holding the fruits at a moderately low temperature. Injured and cracked tomatoes lost weight more rapidly and suffered greater losses in sugar and acids than did sound specimens. Early marketing of tomatoes is recommended because of the rapid decomposition of the desirable sugar and acid constituents.

**Ethylene blanching of celery.**—In studies at the Pennsylvania station 1 part of ethylene to 50,000 parts of air proved more satisfactory for blanching celery than did higher concentrations. At this point was reached the maximum output of carbon dioxide, the evolution of which was apparently stimulated by ethylene. Removal of the carbon dioxide increased the rate of blanching but also increased decay. In the presence of high amounts of carbon dioxide, ethylene at the rate of 1 to 10,000 parts of air failed to induce blanching. A concentration of 1 part of ethylene to 1,000 parts of air caused splitting of the stalks and development of pithiness.

**Viability in sweet corn.**—An interesting method of determining the viability of sweet corn was developed at the Illinois station, where it was noted that dead and weak seeds were much more subject to leaching in distilled water than strong, viable seeds. Observations upon the leachings with a refractometer and colorimeter proved to be more accurate indexes to germination capacity than simple growing tests.

**Asparagus growth.**—At the California station it was found that male asparagus plants are distinctly more productive than females, outyielding the latter by more than 56 per cent in the second cutting season. However, the average weight of the spears was greater in the case of the female plants, the yield gains being due to a larger number of spears in males. Cutting a light crop from asparagus plants the year following setting was found in no way injurious; in fact, the cut plants yielded slightly more the second season than did the controls. Delay in replanting asparagus following removal from the nursery and also root pruning were both injurious as measured by subsequent production.

The satisfactory production of spears secured at the Massachusetts station from asparagus roots planted in sterile sand bore out earlier observations that early spring yields in asparagus are largely dependent on reserve foods. The continued removal of the spears resulted in the production of a larger number but inferior quality spears. There was evidently a region of inhibited growth about the growing spear, the cutting of which resulted in the development of spears from dormant buds.

**Improvement and culture of canning peas.**—That individual plant selection is a successful method for improving canning peas was indicated at the Wisconsin station, where productive strains possessing unusual uniformity in the character of the peas and in time of ripening were developed. Mass selection, on the other hand, was not successful. Mutations occurred only at rare intervals and generally in the form of irregular offtypes. Among desirable new varieties resulting from hybridization is the Horal, a cross between Horsford and Alaska and combining the best qualities of these two well-known varieties. Temperature is the controlling factor in pea production, according to studies at the Maryland station. In general, as the temperature rose yields declined rapidly, the loss being largely in a decreased number of pods rather than in the number and weight of peas in the pods. High temperature was harmful at all

stages of development and is deemed the chief factor in determining yields and growth.

### PLANT DISEASES

The 500 or more plant-disease projects reported as active at the stations during the year show the large amount of attention that is being given to this subject. Some results of the investigations are given below.

**Clover diseases.**—In a study of the causes of clover failures the Kentucky station found that unfavorable conditions, associated with pathogenic organisms, caused most of the failures to maintain a profitable stand of clover in Kentucky and possibly throughout the eastern portion of the United States. Infertile soils, unfavorable temperatures, and drought weaken the plants so that they are an easy prey to parasitic organisms. The addition of lime, manure, and other fertilizers decreased the mortality of clover plants on clover-sick soils.

**Corn diseases.**—Considerable attention has been given to the root rots of corn caused by seed-borne fungi. The Illinois station found that yields were reduced by these fungi as follows: 17.3 per cent by the scutellum rot, 34.2 per cent by *Diplodia zeae*, and 46.6 per cent by *Gibberella saubinetii*. Treating seed corn with some of the mercury phenolate compounds reduced the losses due to various rots, but better results were secured when seed was planted that was nearly free from the fungi. Seed with a hard horny endosperm generally gave better results than starchy seed in experiments at the Illinois and Wisconsin stations. Where disease-free seed is not available, thick planting of the best seed that can be obtained, so that losses through poor germination are overcome, will about equalize the stand from good seed.

The occurrence of a root rot of corn that is independent of the seed-borne fungi is reported by the Kentucky station. The cause of this disease is a soil-borne organism similar to one that has been reported to cause a rotting of the roots of sugar cane. The Missouri station has likewise reported such a disease that is independent of any of the seedling blights. This disease causes a rotting of the roots, resulting in the falling over of the stalks.

A destructive ear rot of corn, caused by *Diplodia zeae*, to which field ears are susceptible at nearly all stages of maturity, was reported by the New York State station. Studies at the Indiana station showed that a considerable number of organisms were associated with rotting of the nodal tissues of cornstalks, but no one organism was found to be the primary agent in causing the decomposition of the tissues. Plants with an abundant potassium supply tended to resist, while those containing an accumulation of iron were susceptible to attack. The Wisconsin station has shown that varietal resistance to seedling blight is due to the greater capacity of such strains to produce well-balanced, vigorous growth under unfavorable environmental conditions.

Corn smut sometimes causes appreciable losses, especially with sweet corn. The Kansas station has found that dusting sweet-corn plants with sulphur or powdered copper sulphate controlled smut to some extent. Varieties of corn varied as to their susceptibility to smut, and evidence was secured that indicates the presence of physiologic forms of the fungus. Independent investigations at the Minnesota station have shown that there are at least seven or eight physiologic forms of corn smut, as shown by their ability to attack varieties and strains of corn.

**Cotton diseases.**—The North Carolina station has found that delinting cottonseed with crude sulphuric acid controls cotton anthracnose and bacterial boll rot. The seed is delinted by the acid in from 10 to 15 minutes, but leaving it in the acid for from 20 to 24 hours did no injury, and in some cases it hastened germination. The Arkansas station reports that the same treatment controls angular leaf spot. The Tennessee station got similar but more economical results with sulphuric acid diluted 1 part acid to 10 parts water. Pathologists attached to the Arkansas and Mississippi stations have recently shown that the wilting of cotton attacked by Fusarium is not due to a plugging of the water-conducting vessels, but is caused by toxic substances secreted by the fungus.

**Oat diseases.**—Investigations at the Minnesota station have shown that there are at least five physiologic forms of crown rust and five of stem rust of oats. In attempts to develop resistant varieties of oats the existence of these forms must be recognized. The Kansas station found that the hulls on oats afford a certain amount of protection from attack by

oat smut, dehulled seed of the most resistant varieties being readily infected.

**Pea diseases.**—Continued studies of pea diseases at the Wisconsin station have shown the occurrence of two new species and a new form of Ascochyta, all of which are carried over from crop to crop on the seed and cause a blight of the plants. One of the forms was found to persist in the soil, and it is believed that it may prove quite destructive under field conditions. Investigations of bacterial blight of peas, conducted at the same station, are said to indicate that the organism winters over in a dried film on the seed and seed coats. The use of seed treatment for control is believed to be practicable. The New Jersey stations report that the fungus *Aphanomyces euteiches*, which causes root rot of peas, may also attack cowpeas, vetch, and sweet clover. It was controlled in the field to some extent by applying hydrated lime at the rate of 2 tons per acre. Sulphur applied to the soil controlled the disease, but it also injured the pea plants.

**Potato diseases.**—Cooperative investigations of the Maine and Florida stations have shown that the early blight fungus, *Alternaria solani*, not only attacks the tops of the plants but it may cause a rotting of the tubers. Tubers thoroughly mixed with infected tops in Maine and later shipped to the Florida station for early planting, showed the presence of small spots on the tubers which developed rots and also served for the spread of the early blight to the plants as they developed.

The so-called virus or degeneration diseases of potatoes and related plants continue to receive much attention by station plant pathologists. The Nebraska and Kansas stations consider spindle tuber the most important disease of this type in their States. Under the high temperatures that often prevail the symptoms are masked to reappear when the tubers are planted in other regions. Even when the symptoms are not evident the yield is reduced. While insects have been shown to be the causes of spreading some of the degeneration diseases, none was found by the Nebraska station to be associated with spindle tuber. The cutting knife is believed to be the principal means whereby this disease is spread. Unsuccessful efforts were made by the Nebraska station to transmit by tuber grafts the degeneration diseases calico, weather mottle, and witches'-broom. The Montana station claims that witches'-broom was readily transmitted to other potato plants by tuber core grafting, and to tomatoes by inarching the plants. The Washington station successfully transmitted giant hill by core grafting of tubers, but failed with witches'-broom and chlorosis. Experiments at the New York Cornell station have shown that tobacco mosaic was readily transmitted to potatoes where symptoms were produced that differed with the varieties used. A serious disease of peppers was produced by inoculating the plants with sap from apparently healthy potato tubers.

With the present state of information regarding the degeneration diseases of potatoes, it is considered advisable to secure for planting seed potatoes as free as possible from disease. Where potatoes are grown for seed purposes only, tuber indexing combined with roguing in the field has produced nearly disease-free stocks. The Utah station claims to have completely eliminated rugose mosaic and leaf roll, and greatly reduced spindle tuber by this method. At the Wisconsin station, from a stock that showed 15 to 40 per cent mosaic, planting material was secured showing 3 per cent or less of mosaic. At the Nebraska station mosaic was reduced in two years from 38.2 per cent to 0.7 per cent by tuber indexing and roguing.

**Sugar-beet diseases.**—Investigations at the Michigan station have shown serious losses due to a number of fungi which are seed borne. Where injurious organisms were not present in the soil, planting seed that had been heated for 10 minutes at 60° C. (140° F.) on two consecutive days prevented loss from seed-borne fungi. Some of the new mercury and copper fungicides reduced the amount of loss due to diseases, but the mercury dusts were considered too costly for field use.

In a series of infection experiments with the curly top of sugar beets, the California station found that the virus of the disease infected 16 genera of plants which included 25 species and 46 horticultural varieties belonging to the families Chenopodiaceae, Leguminosae, Cucurbitaceae, Solanaceae, Cruciferae, and Umbelliferae.

**Tobacco diseases.**—Recent experiments at the Kentucky station are said to indicate that frenching of tobacco is a nutritional disorder of the plant, and it occurs when the rate of carbohydrate metabolism is in excess of nitrogen absorption; in other words, frenching is due to a deficiency of nitrogen in the plant.

A disease of tobacco called ring spot was investigated by the Virginia station, and while the disease was found to be infectious no causal organism was observed.

Tobacco mosaic can be conveyed through natural leaf used for smoking or chewing, and by certain brands of cigarettes and granulated smoking tobacco, according to investigations by the Kentucky station. Inoculation experiments with the mild type of tobacco mosaic reduced the yield of Burley tobacco one-third when the plants were infected at the time of setting in the field. When inoculated at the time of topping the yield was not reduced, but the value of the crop was reduced by 25 per cent due to lower grades of the product. The Wisconsin station has shown the existence of at least 11 different viruses of tobacco and related plants, most of which are relatively stable, although some were capable of attenuation as well as increased virulence through laboratory manipulation. The Iowa station reports the occurrence of three main types of mosaic diseases, one of which is confined to the Solanaceae, a second to cucurbitaceous plants, and the third occurs on sweet clover. All can be successfully transmitted to tobacco. Studies at the Wisconsin station appear to prove that the causal agency of tobacco mosaic is not a living agency, but it is believed to be a simple colloid possibly of a protein nature. Experiments at the California station apparently confirm this conclusion, as it was found that infections decreased with the dilution of the virus and there was no indication of the virus increasing under conditions favorable for growth.

Black root rot of tobacco (*Thielavia basicola*) has been found by the Massachusetts station to be less injurious in acid soils than in nearly neutral soils and it may be in a measure controlled by increasing the acidity of the soil. Liming favored development of the disease, while applications of sulphur and various acids, especially sulphuric and nitric acids, produced soil conditions unfavorable to the rot.

**Wheat diseases.**—Tests of more than 250 varieties of wheat at the Minnesota station showed that no variety was immune to wheat scab, although there were marked differences in the degree of susceptibility. Studies at the same station of *Helminthosporium sativum*, the cause of basal rot of wheat and other cereals, showed that there was a large number of physiologic forms of the fungus and no variety of wheat was immune to all the forms. There was a considerable degree of variation in susceptibility in varieties, the durum wheats appearing most susceptible to basal and root rots.

Efforts to eliminate the barberry as a source of rust infection of wheat were continued by a number of the stations. Coarse salt piled about the bushes has been found one of the cheapest and most effective means for the destruction of the bushes. Some of the stations are carrying on experiments for the biological control of rusts. The Kansas station reports having produced second and third generations of plants resulting from crosses between Kanred and Fulcaster, and some of the new varieties are quite resistant to leaf rust. Plants that were immune to rust in their seedling stages continued to be resistant in the later stages of growth. Dusting wheat plants in the greenhouse and field with sulphur was found to prevent leaf-rust infection. The Nebraska station found that over a period of six years stem-rust infection appeared on grains and grasses an average of 11 days earlier in the presence of infected barberry bushes than from wind-blown spores of remote origin. Tests were made of nearly 600 pure lines of wheat, and while none was found immune to all the 14 physiologic forms of stem rust tested, some were very promising in their degree of resistance. The Minnesota station tested a number of crossbred wheats for their resistance to physiologic form 1 of wheat stem rust, and immunity was found dominant to susceptibility. As no structural differences were noted in the plants the reaction to the rust is considered to be due to physiological causes.

The undoubted occurrence of physiologic forms of loose smuts of wheat and barley is reported by the Minnesota station, which found that spore material from different sources reacted differently on varieties of the grains. Similar results were obtained with studies of the stinking smuts of wheat and oats. Recent reports from the Oregon and Washington stations indicate specialized forms of bunt or stinking smut on wheat in those States. At the Kansas station the effect of dates of planting wheat on the occurrence of stinking smut was investigated, and it was found that early plantings in September, when the soil was warm, showed little smut infec-

tion, while later plantings in October to November 15 resulted in the highest infestations.

**Apple diseases.**—A new bark canker of apple trees caused by *Glutinium macrosporum* has been described from the Oregon station. In addition to forming cankers on the trees, the fungus also causes a rotting of the fruit. Pear trees are similarly affected.

Additional studies of fire blight have been reported by the Wisconsin station. Fully 90 per cent of the twig infections in the early season of 1925 was traced to water-borne inoculum from existing cankers. Overwintering cankers were found on twigs as small as three-sixteenths inch in diameter. Plant lice and leafhoppers are considered the chief insect spreaders of twig blight in orchards, and they may be important factors in the initial spread to the blossoms. Bees were found the chief agents of spreading the blossom blight. Considerable differences were noted in varietal resistance to fire blight, but even the most resistant varieties became heavily infected when succulent growth was promoted by cultivation, pruning, and fertilizing. Further investigations at the Pennsylvania station of the organism *Bacillus amylovorus*, the cause of fire blight, have shown that the bacteria migrate through the tissues in the form of zoogloea In the earliest stages the migration is mostly between the cells, and cavities are produced through the splitting apart of the cells or by the dissolution of the cell walls. Most of the migration takes place while the organisms are in a vegetative stage, but later a cyst form occurs which represents the overwintering form.

Tests of more than 500 pear seedlings derived from *Pyrus callaryana*, all of which were susceptible to fire blight, are reported by the Illinois station. Bartlett pears top-worked on *P. ussuriensis* also blighted. Cutting out the cankers, as usually done by growers, did not control fire blight on apple or pear trees.

A severe twig infection by cedar rust in the fall of 1926 is reported by the Arkansas station. Leaf and fruit infections were noted on some varieties, but the most injury was to nursery stock, the stems being girdled a foot or more above the crown.

Apple blotch can be controlled, according to the Indiana station, by spraying the trees at petal fall and at two-week intervals until four applications are given. Lime-sulphur was found best for the first spray and Bordeaux mixture for the following ones. A 2–6–50 Bordeaux was generally preferred. Weaker ones did not give good control in some seasons. It is claimed that in young orchards cutting out the cankers and thorough spraying for four or five years will remove the necessity for further annual spraying for blotch control.

Moisture and temperature play an important part in the severity of attack of apple scab and the difficulty of its control, according to the Wisconsin station. A temperature of about 68° F., accompanied with suitable moisture, is most favorable for the fungus attack, and the leaves and young fruits are most susceptible to infection. Under Wisconsin conditions the fungus overwinters in fallen leaves, and these should be destroyed where possible. Spraying with Bordeaux mixture and lime-sulphur controlled scab, but there was some injury to the foliage and fruit from Bordeaux mixture. Lime-sulphur (1 to 40) was on the whole the most satisfactory spray tested. From a study of the time of ascospore discharge from fallen leaves the New Jersey stations conclude that while a spray application before the pink stage of the blossoms may be unnecessary in the central and southern parts of the State, in the northern part of the State a dormant or prepink application is needed for the control of scab.

Internal browning of Jonathan apples appears, from investigations at the Utah station, to be more frequent on well-drained bench lands than on heavier, more retentive soils. The trouble was increased by allowing the fruit to remain on the trees a week or more after the normal time of harvesting.

A blackening of the end of apples is reported by the Virginia station. The trouble is believed to be due to a physiological disorder of the trees probably induced by drought. The same station found that black walnut trees growing near apple trees exert a decided toxic effect on the latter. Walnut trees 75 to 80 feet away are believed responsible for the death of apple trees. No correlation was found between the spread of walnut limbs and the extent of the toxic effect.

**Blackberry diseases.**—A dwarfing of blackberries, especially of the vining type, as, for example, Phenomenal and Logan, is said to be severe in Oregon. The canes are reduced, very leafy, with dwarfed, light-colored leaflets, and the berries drop apart after harvest. The

disease is thought to belong to the virus type, and roguing of all plantings is advised.

**Crown gall of nursery stock.**—The relation of crown galls caused by *Bacterium tumefaciens* to other overgrowths of nursery stock continues to be a subject of investigation at a number of stations. The Iowa station reports the isolation of the organism from less than 20 per cent of the overgrowths on young apple trees, and at the Wisconsin station a critical examination of over 400 apple trees that had been rejected at 22 nurseries in 14 States showed the presence of *B. tumefaciens* in only 14 per cent. The other overgrowths are considered to be due to faulty grafting or wounds during cultivation. In experiments where proper grafting methods were employed, or where stock was propagated by budding, no wound overgrowths were observed.

**Peach diseases.**—The Delaware station claims to have found conclusive evidence that *Bacterium pruni*, the cause of bacterial leaf spot of the peach, overwinters in cankers on the tree. No direct proof of bud infection was found. Preliminary experiments indicate that the disease may be controlled by spraying with sodium fluoride, cresol, or chlorophenol mercury. The Illinois station reports almost perfect control with sodium silicofluoride.

The important rôle of mummy peaches in carrying over winter the fungus which causes the brown rot of the peach was shown in investigations of the Maryland station. It is suggested that all dried mummy peaches should be plowed under in the fall or early spring and not be allowed to lie on the surface of the ground to develop the fruiting stage of the fungus and serve to spread it to the coming crop.

Dormant strength lime-sulphur applied in the fall or Bordeaux mixture-oil emulsion applied either in the fall or early spring will control peach leaf curl, according to the Illinois station. If applied after the buds begin to swell neither treatment will prevent leaf curl.

**Raspberry diseases.**—The New York State station reports that the growing of red raspberries in certain parts of the State has been abandoned on account of raspberry mosaic. Some of the purple and black varieties are also subject to attack, but not so severely as the red varieties. The disease has been found to be carried from plant to plant by *Aphis rubiphila*. Roguing plantings at Geneva was effective in controlling the disease, but it is stated that in the lower Hudson River Valley only resistant varieties can be successfully grown.

A new virus disease of black raspberries that is quite destructive has been recently reported by the same station. The symptoms of this disease are quite different from the mosaic of red raspberries, and it is believed that the trouble has been confused previously with wilt and streak. The Michigan station has recognized five distinct virus diseases of the raspberry—curl, red raspberry mosaic, mild mosaic, yellow mosaic, and streak. Evidence has been obtained which indicates that all forms of these diseases are carried from plant to plant by aphids. Planting resistant varieties and roguing are suggested as control measures.

**Strawberry diseases.**—The Oregon station has described, under the name witches'-broom, a new mosaic disease of strawberries in western Oregon. It is characterized by dwarfing of the plants, shortening of the runners, and light color of the affected leaflets which usually curl downward. Some varieties of strawberries appear more susceptible to the disease than others. Witches'-broom is spread by plant lice.

**Bean diseases.**—The New York Cornell station has reported a new bacterial disease of the common bean, which is thought to be due to a variety of the organism that is known to cause a wilting of alfalfa. Severe injury was caused in fields of red kidney beans. Scarlet runner and Lima beans are also subject to attack. An abnormality of beans that resembles mosaic has been observed by the same station. This condition appears to be inherited and it is not infective so far as is known. Bean mosaic was found at the Indiana station to affect velvet bean, broad bean, scarlet runner bean, asparagus bean, and cowpea. Investigations at the Idaho station appear to indicate that the sugar-beet curly top disease is conveyed to beans by the leaf hopper *Eutettix tenella*.

**Cabbage diseases.**—The Delaware station reports severe injury to cabbage plants in the greenhouse due to watering the plants through copper screens used for their protection against insects. Generally a soft rot followed the copper injury and the plants soon died. The Wisconsin station has announced the development of three mid-season varieties of cabbage that are resistant to yellows. The varieties were developed by selection, hybridization, and field testing, and they are considered satisfactory for commercial

use on badly infested soil. The new varieties are called Globe, Marion Market, and All Head Select, and they were derived from Glory of Enkhuisen, Copenhagen Market, and All Head Early, respectively.

**Celery diseases.**—Experiments at the Minnesota station have shown that the heart rot of celery, as it exists in the more northern States, is caused by bacteria, and the disease is spread by two species of leaf-mining insects.

**Tomato diseases.**—Investigations at the West Virginia station are said to show that the strain of *Phytophthora infestans* which causes late blight of tomatoes is biologically different from the one which causes late blight of the potato. The fungus transferred from the potato infected tomato plants but not the fruit unless the skin was broken. In every observed case the blight appeared earlier on the potato than on the tomato, and wherever it was found on tomatoes, potato blight was present near by.

The effect of mosaic on the tomato plant was investigated at the Minnesota station and it was found that in badly infested leaves there was little or no difference in the size of the cells in the sound and chlorotic areas, but the chloroplasts in the diseased areas were lacking or few in number. Somewhat similar studies at the Indiana station showed reduced weight of the mosaic plants due to a reduction of the total carbohydrates. Experiments to determine the effect of different soil conditions on mosaic did not show that they affected the character or severity of the disease.

Tomato plants in many parts of the country are subject to a wilt caused by *Fusarium oxysporum*, and a number of stations have turned their attention to the production of varieties of tomatoes that are resistant to the disease. Studies at the Kansas station have shown wide variation in the virulence of strains of the fungus obtained from different localities. Cultures of the fungus in the laboratory showed that it produced two classes of substances that were highly toxic to susceptible tomato plants. One of them is of a colloidal nature and the other crystalloidal. Plants of strains of tomatoes that were resistant to wilt were not affected by these toxic substances, but susceptible ones were quickly destroyed.

For a number of years the western yellow blight of tomatoes has been a problem, especially in the northwestern part of the country. Recent studies at the Idaho, Washington, Oregon, and California stations have apparently connected the disease with the curly-top disease of sugar beets. Experiments at the Oregon station showed that the western yellow blight of tomatoes was produced when healthy plants received leaf hoppers that had been feeding on sugar beets affected with curly top. Similar experimental evidence was secured at the California station, where curly top was produced on sugar beets by transferring to them leaf hoppers that had fed on tomatoes affected with western yellow blight.

**Transportational diseases.**—On account of the large losses of fruits and vegetables in transit to market or in storage some of the stations have turned their attention to solving these new problems. The Michigan station investigated black leaf speck of cabbage and cauliflower, red heart of lettuce, and surface pitting and black heart of potatoes, and found that they were caused by defective conditions in storage and transportation, resulting in an inadequate oxygen supply and temperatures that did not permit the products to utilize the oxygen present. The breakdown diseases were produced under controlled conditions, in which it was found that stagnant air or air circulation without renewal and low temperatures were responsible for the condition of breakdown.

### CONTROL

One of the important objects of a study of plant diseases is the discovery of means for their control. During the year a number of stations have made rather definite suggestions for the prevention of losses in various crops. Some of the findings are given below.

**Oat diseases.**—The Idaho station reports experiments with formalin, corrosive sublimate, copper carbonate, and a number of proprietary compounds for the control of smut of both hulled and hull-less oats. All the dust treatments controlled smut to some degree, but none was as efficient as the copper carbonate and corrosive sublimate treatments. Formalin affected the germination of the hull-less oats. Perfect control was secured with a dust mixture consisting of two parts corrosive sublimate and one part of finely pulverized soil used at the rate of 3 ounces per bushel. At the Kansas station some of the organic mercury and phenol compounds were tested for smut control in comparison with for-

maldehyde and copper carbonate. None was as effective as formaldehyde. Dusting the seed grain with copper carbonate and various forms of sulphur gave good control with the hull-less varieties of oats, but the treatments were less effective when used with hulled varieties. The Ohio station has been trying to reduce the cost of seed treatments for smut control, the dusts usually recommended being considered too expensive for general use. A mixture of formaldehyde with infusorial earth was made, and when dusts containing 10, 15, and 20 per cent of the 40 per cent formaldehyde were used at the rate of 3 ounces per bushel of seed grain less than 1 per cent smut was found in plats, as compared with 47 per cent for check lots. The cost was less than 5 cents per bushel of seed treated. A finely ground iodine mixed with infusorial earth in the proportion of 5 per cent iodine also gave nearly perfect control of oat smut.

**Potato diseases.**—The Minnesota station, as a result of experiments covering three years for the control of scab and Rhizoctonia, claims that treating the seed tubers with corrosive sublimate solution before planting gave average increased yields of 44.1 bushels per acre and treatment with hot formaldehyde increased yields by 41.4 bushels. Over a 5-year period, spraying the plants in the field with Bordeaux mixture for the control of late blight and flea beetles gave an increased yield of 25.08 bushels. As a result of 15 years' experiments three sprayings with Bordeaux mixture were profitable every year except two, when flea beetles were very abundant. Under such conditions additional sprayings were considered advisable. The Maine station, as a result of 28 years' experiments, found spraying for the control of early and late blight, and incidentally the control of flea beetles and leaf hoppers, fully justified when the cost of spraying was not greater than the value of a 20 per cent increase in the crop. Bordeaux mixture spraying was generally the best method of application. Copper-lime dust controlled late blight when an equal amount of copper was applied, as in Bordeaux mixture, but it was inferior for the control of early blight and flea beetles.

**Sorghum and millet diseases.**—The Kansas station reports that the most effective and economical dust for the treatment of sorghum and millet smut control was copper carbonate used at the rate of 4 ounces per bushel of seed. Formaldehyde seriously injured the germination of treated seed.

**Wheat diseases.**—Experiments of the Minnesota station have shown that stem rust of wheat can be controlled, even under epidemic conditions, by dusting the plants with precipitated sulphur. For effective control, dustings should be made at 4 or 5 day intervals between the time of flowering of the plants and the soft dough stage of the grain. Similar results were secured by the New York Cornell station.

Continued experiments in the control of bunt or stinking smut of wheat have shown the value of copper carbonate for preventing losses due to smut. The California station considers copper carbonate the most satisfactory fungicide for treating wheat on account of its efficiency and ease of application. Tests of 20 or more compounds by the Idaho station showed that none was superior to copper carbonate, when cost, seed injury, ease of application, and efficiency of control were considered. At the Kansas station copper carbonate containing 50 to 55 per cent copper gave the best control of stinking smut. Experiments at the Utah station indicate that slightly better control of wheat smut was reported for formalin and copper sulphate treatments than for copper carbonate.

**Apple diseases.**—The New Jersey stations found that the use of concentrated lime-sulphur was not satisfactory for the control of apple blotch where the disease had been severe during previous seasons. Under such conditions lime-sulphur applications supplemented with Bordeaux mixture four and six weeks after petal fall gave good control. The Wisconsin station claims that commercial lime-sulphur and sulphur dusts in the concentrations usually recommended prevent apple-leaf infection by scab better than Bordeaux mixture. The Ohio station has worked out a method for determining the best time for spraying for the control of apple scab. It is based on the spore discharge of the fungus, and to be most effective applications should be made just before periods of spore expulsion.

**Cherry diseases.**—The New York State station cautions orchardists on the use of acid lead arsenate either alone or in combination with a fungicide, as it was found to be responsible for a pedicel injury to the fruit that resulted in dwarfing, shriveling, and dropping of cherries and plums.

**Cranberry diseases.**—At the New Jersey stations comparative tests were made of dusts and sprays for the control of cranberry diseases. Bordeaux mixture generally gave the best results. Copper-lime dust did not adhere very well and was not so effective. Copper carbonate and colloidal sulphur did not control various rot fungi. Sulphur used as a dust injured the fruit and foliage.

**Cabbage diseases.**—From experiments conducted by the New York State station at the branch station on Long Island it was found that one or two applications of a 1 to 2,000 solution of corrosive sublimate to cabbage and allied plants while still in the seed beds controlled the cabbage maggot, reduced clubroot, and practically eliminated infection by blackleg and black rot.

**Cucumber diseases.**—Investigations by the New York State station indicate that cucumber wilt and mosaic may be controlled to a considerable extent by applications directed against the striped cucumber beetle, which spreads both diseases. Wilt was controlled by spraying with Bordeaux mixture, to which lead arsenate was added, or dusting with lead-arsenate-lime mixture. Mosaic was reduced by sprays, but dusts were less satisfactory. Plants sprayed with Bordeaux mixture remained green later in the fall than dusted plants.

**Tomato diseases.**—The New York Cornell station has shown that soil treatments with copper carbonate, corrosive sublimate, and Uspulun controlled damping-off of tomato plants in greenhouses where the causal agent was Phytophthora. Treatments with mercury compounds controlled Rhizoctonia, while copper carbonate and colloidal copper did not do so. Mercury compounds caused injury to tomato plants in concentrations that did not injure cabbage plants. Treatments after damping-off had appeared were of little value in controlling the further spread of the disease.

**Damping-off of coniferous seedlings.**—From a number of fungicidal treatments tested by the Ohio station for the control of damping-off of coniferous seedlings in seed beds it was found that the use of a 3 per cent formaldehyde solution gave the best results. Organic mercury compounds were unsatisfactory, and the other materials tested were valueless for the control of the diseases, or they injured germination.

**Spray materials.**—The Massachusetts station has been engaged on a study of the form and proportion of lime to be used and the best method for mixing Bordeaux mixture. Limewater was found to be the most active and the material was entirely soluble. Precipitated lime furnished a finely divided uniform precipitate that approached limewater in its activity. Milk of lime varied with the quality of the lime used and thoroughness of shaking. Commercial hydrated lime varied, but some of the best grades approached freshly slaked lime in activity, and it is believed that good hydrated lime can be used in place of quicklime, which is difficult to slake and often contains much inert material. The best method for preparing Bordeaux mixture is said to be to pour the dilute copper into the concentrated lime, or the two simultaneously into a third receptacle. The same station reported the preparation of a basic copper sulphate that can be used as a spray or dust in place of Bordeaux mixture for the control of a number of plant diseases. It is said to be effective as a fungicide, easily applied, and of reasonable suspension, distribution, and adhesiveness.

Precipitated sulphur as a spray was not quite so effective as was lime-sulphur, in experiments at the Ohio station, although it was better than dusts, dry-mix lime-sulphur, or wettable sulphur. Precipitated sulphur caused no foliage injury to any plant tested. Colloidal sulphur caused some burning of the foliage of apples, peaches, cherries, plums, and grapes.

Sodium silicofluoride is being widely recommended for the control of various plant diseases, but the Illinois station suggests that it should be used with caution until its effect on foliage and fruit is better known. In experiments with this material for the control of the bacteral spot of peaches one series was highly satisfactory, while in another there was some injury to the foliage and the quality of the fruit was materially reduced.

## ENTOMOLOGY

**Oriental fruit moth.**—This pest from the Orient continued to spread and was a source of increasing injury except in old established areas, where in some orchards of Elberta and later peaches the injury was reduced from about 26 to less than 10 per cent of that of previous seasons, due largely to the increasing efficiency of parasites. At the New Jersey stations 21 different parasites were reared, one of which, very prevalent during the two preced-

ing years, appeared to have been responsible for the enormous reduction in the injury caused by the moth in that State. The same stations found that the efficiency of nicotine sulphate has been considerably underestimated, since a dilution of 1:800 destroyed 67 per cent of the eggs and larvae. During a three-year period, cultivation and the use of paradichlorobenzene about the trunk destroyed 86 per cent of the hibernating larvae. It appears that there is an overwintering population in the upper portions of the tree which perpetuates the infestation in spite of the application of such measures. At the Pennsylvania station it was found that bait pails can be used with advantage in capturing this moth without destroying beneficial insects in alarming numbers. Nonfermenting baits showed a longer period of activity and may prove more practical for control purposes, although fermenting baits trapped larger numbers.

**Codling moth.**—In continued study of this old and important enemy, particularly of the apple and pear, the stations gave particular attention to search for an insecticide that will effectively destroy the worms without leaving a residue of lead and arsenic on the fruit. No satisfactory substitute for lead arsenate has yet been discovered. Feeding of the insect upon soft fruits was recorded by the Colorado station, at times seriously injuring plums, prunes, and apricots, and sweet cherry and peach were also attacked. The Oregon station has also reared the insect from larvae feeding upon cherries. Resistance of apples to the pest, according to the Delaware station, appears to be connected with the toughness of the skin. The New Jersey stations found that the effective temperature required for development and observations on emergence in cages form a good indicator of the time when spraying for side worms of the first brood should take place. The use of the bait pan for determining dates of emergence appears to be chiefly important where the infestation of the previous year has been large. Cooperative control work based upon such knowledge resulted in a remarkable reduction in codling moth infestation. At the Washington station the mush bowl was found to catch more than three times as many moths as the fruit jar, when a mixture of apple cider, brown sugar, and yeast was used as a bait. It was found that the moths do most of their flying in tree tops and that traps placed in the extreme top are more effective than those placed nearer the ground.

**European corn borer.**—This invader from the Old World, first discovered in the vicinity of Boston, Mass., in 1917, appeared south of Buffalo, N. Y., in the fall of 1919, and has since spread north and south of Lake Erie and is advancing into the Corn Belt. The stations in the infested States, cooperating with the United States Department of Agriculture, have conducted investigations and an intensive clean-up campaign with a view to checking its spread. In studies of the life history and bionomics of this insect, conducted at the New Hampshire station, in the eastern infested area, it was found that both one and two generations of the insect develop from the overwintering individual. The development of the borers of the second generation was hindered by cool weather, only part of the larvae being able to enter hibernation successfully. The Ohio station found that the longer corn is allowed to stand after it matures the lower down the borers make their way and the greater the number left in the stubble. Shredding the fodder destroyed 95 per cent of the borers that passed through the shredder, while cutting infested stalks into lengths of 1 inch or less destroyed practically all the borers.

**Japanese beetle.**—This oriental pest continued to spread and to increase in intensity of infestation. The New Jersey stations found the grubs unable to survive in cranberry bogs flowed for a period of four months during the winter and spring.

**Mexican bean beetle.**—The spread of this beetle continued during the year. The Kentucky station found that calcium arsenate and lime applied both as a spray and as a dust gave slightly better protection than the other insecticides employed, the liquid spray giving slightly better control than the dust.

**Cotton boll weevil.**—The work with this pest was directed particularly at control by insecticides. Studies by the Texas station showed that the greater part of the poison that kills is picked up by the weevil in traveling over the plant rather than while actually feeding. At the Florida station a mixture consisting of 1 pound calcium arsenate, 1 gallon water, and 1 gallon sirup was more effective in its resistance to rain, drying, and surface caking, as well as being cheaper than the more concentrated mixtures commonly

recommended. Sodium fluosilicate was found by the North Carolina station to be more effective against it than calcium arsenate, to reach its effectiveness in less than half the time, and to act as a repellent as well as an insecticide.

**Cotton flea hopper.**—This insect, which has caused serious injury to cotton in several States during the last few years, continued to receive attention. At the Alabama station a mixture composed of 50 per cent sulphur and 50 per cent calcium cyanide, the cyanide content being from 17 to 25 per cent, gave good control when applied once a week at the rate of 8 to 10 pounds per acre, no burning of the foliage resulting from the application. The Georgia station obtained good results from dusting cotton with sulphur, especially as regards gain in yield from the first two pickings. Sulphur dust applied by the Texas station under favorable conditions at the rate of 20 pounds per acre effectively controlled the flea hopper for a period of from six to seven days.

**Plant lice or aphids.**—Considerable attention continued to be given to this large and important group of insects, especially to studies of their life history, which is complicated by their numerous forms and generations, and migration to summer host plants. Observations by the California station indicate that the mealy plum aphid passes the winter in the egg stage on the fruit trees, no evidence being found that the late fall adults hibernate on cat-tails and reed grasses as previously supposed. This station also concluded that the melon aphid and *Aphis spiraecola* on citrus represent two distinct species, both of which are widely distributed over the citrus area. The variable currant aphid (*A. varians*) and the green gooseberry aphid (*A. sanborni*) were found by the Maine station to migrate to and establish summer colonies on willowherb (Epilobium), returning to their primary food plants late in the season.

**Dusky leaf roller.**—The Pennsylvania station observed that the dusky leaf roller (*Amorbia humerosana*) rolls the leaves and feeds upon both foliage and fruit of the apple, the deep cavities eaten in the fruit seriously affecting the quality. It was found to be single brooded, hiberating in the pupal stage.

**Peach cottony scale.**—The New York State station found that this insect, which has been causing serious injury to peach orchards in the lake region of western New York, can be controlled by spraying with 4 per cent lubricating-oil mixtures, a homemade mixture consisting of red engine oil, 2 gallons; water, 1 gallon; and potash fish-oil soap, 2 pounds, being the most economical.

**Cranberry weevil.**—The Massachusetts station found spraying with a mixture of Bordeaux, calcium arsenate, lime, and fish-oil soap to be an efficient means of controlling the cranberry weevil.

**Black army cutworm.**—The cutworm *Agrotis fennica*, which caused tremendous damage to the blueberry crop in Maine in 1925, was found by the station of that State to be most effectively controlled by the use of a poison bait, consisting of bran, Paris green or finely ground white arsenic, molasses, and water.

**Potato tuber worm.**—This pest, which has been causing considerable injury on the eastern shore of Virginia, was found by the station of that State to have survived out of doors during the winter of 1925–26 in the pupal stage only. In the storage houses, where the temperatures remained above freezing, all stages survived. Infestation of spring crop fields was traceable to culls and volunteers.

**Sugar-cane borer.**—Silicofluoride dust applied by airplane at the rate of about 20 pounds per acre was found by the Louisiana stations to give effective control of the sugar-cane borer. The effectiveness of this dust depends principally upon the water-soluble elements, which act both as a stomach and a contact poison to the borer. The larvae may succumb within an hour from contact with the dust or from being wet with a solution of it. The eggs of the Trichogramma parasite of the borer were not destroyed by the dust. The tests demonstrated the possibility of destroying two-thirds or more of the borer larvae in corn or in cane, and that the addition of 10 per cent by weight of hydrated lime decreases the tendency to burn the foliage of both crops. It was found that the moths prefer thriftily growing corn rather than sugar cane on which to deposit their eggs. Approximately two-thirds of the borers present in infested corn were destroyed by one application of sodium fluoride by hand dusting, four applications being necessary to cover developments during the first two generations. The fluoride was dissolved by dews and rains, thus washing the entire stalk.

**Hawaiian beet webworm.**—This webworm, which is a source of injury to the beet in Hawaii, was studied by the Virginia station, in which State it appeared as a new pest of spinach. Applications of arsenical sprays and dusts failed to control it, but it was found that most of the spinach planted after September 1 remained uninjured.

**Wireworms.**—These important enemies of the roots of crops were investigated by the Idaho station. The false wireworm (*Eleodes hispilabris*), which is injurious to dry-farmed wheat in Idaho, was found to be effectively destroyed by an arsenical bran bait. The Kansas station found the average depth at which wireworms hibernate to have been 7.7 inches in 1922–23 and 10.1 inches in 1925–26. They were frequently found, however, nearer the surface even in midwinter, although some went to a depth of 36 inches.

**Oil sprays.**—A complete kill of the red scale on lemons was obtained by the California station through the application of a 2 per cent nonvolatile lubricating oil with 98 per cent water as a carrier. The same station found that highly refined lubricating-oil emulsions are very effective against all stages of the common red spider if applied when the infestation first takes place. It was found by the New Jersey stations that the principal oil emulsions and miscible oils have approximately the same value in their effect upon the eggs of the European red mite on both peach and apple. Work at the Mississippi station indicated that a 3 per cent heated emulsion spray will control the obscure scale. That a greater penetration into the tracheal tubes of an insect results from the application of kerosene spray than had been supposed was indicated by studies at the New Jersey stations. The application of miscible oil by the New York Cornell station at the rate of 1 part to 20 parts warm water gave quite satisfactory control of the spruce gall aphid.

**Paradichlorobenzene.**—This insecticide, dissolved in soluble pine-tar creosote and applied at a strength of 1 part to 2 parts of water, was found by the New Jersey stations to penetrate the galleries of borers in the bark of linden trees and in some cases to follow them for several inches. It was also used effectively against borers in the pussy willow, no injury being caused even when used undiluted. The Ohio station concluded that this insecticide could be satisfactorily and safely employed in combating the black peach aphid. The underground form of the woolly apple aphid in nurseries was satisfactorily controlled by the Tennessee station through the application of this insecticide in the soil on both sides of the trees at a depth of 2 inches.

**Fluosilicates.**—Sodium and calcium fluosilicates were the only insecticides tested at the Arkansas station which actually killed large numbers of the striped cucumber beetle and at the same time protected the plant for a number of days against the migrating beetles. It was found that sodium fluosilicate, which was the most effectice, should be diluted with two parts of lime to prevent its occasional injury to plants. Sodium fluosilicate used in grasshopper baits was found by the Colorado station to give a 100 per cent kill in four days as compared with a 98.7 per cent kill by Paris green bait in six days. The Tennessee station found the fluosilicates to be more effective than the relatively insoluble fluorides, to kill more rapidly, and to be cheaper and more readily obtained in commercial quantities.

**Calcium cyanide.**—The California station found less leakage of gas through the tent when calcium cyanide was used in the fumigation of citrus trees than when liquid hydrocyanic acid was employed. Cyanide dust was demonstrated by the Delaware station to have better killing powers than nicotine-lime dust when used against the grape leaf hopper. At the Florida station about 95 per cent of the white fly larvae and purple scale and 96 per cent of the Florida red scale on citrus were killed by fumigation with the cyanide. Diluted with two parts of sulphur, it was found by the North Carolina station to satisfactorily control the bean leaf hopper. In New Jersey, applying calcium cyanide in the open furrow with a special machine attached to the beam plow and promptly covering it with the turning furrow slice destroyed 86 per cent of the wireworms. In greenhouse fumigation at the Missouri station it was found that white flies, plant lice, and scale were killed by a dosage much below that injurious to most greenhouse plants.

**Poison baits.**—Molasses was found by the Nebraska station to actually reduce the attractiveness of baits poisoned with white arsenic for grasshopper control. Molasses, however, increased the attractiveness of baits poisoned with sodium arsenite solution. A homemade bait consisting of 95 pounds of ground dried apple waste mixed with 5 pounds of powdered poison was found by the Oregon sta-

tion to kill the adults of strawberry root weevils.

**Other insecticides.**—A spray consisting of pyridine extract was found by the California station to be the most satisfactory treatment for the corn-ear worm. At the Idaho station a single application of arsenical completely eradicated the snowy tree cricket in a prune orchard and prevented loss entirely for the season. A mixture of lead arsenate 1 pound and gypsum 5 pounds was the most effective of the arsenicals tested against the strawberry leaf roller by the Iowa station. Lead arsenate 1 pound and land plaster 10 pounds used at the rate of 20 to 70 pounds per acre gave higher yields than weaker mixtures when used against the striped cucumber beetle at the Kentucky station. Powdered lime sulphur applied at the rate of 16.5 pounds to 50 gallons of water and 1 quart of a miscible oil to 20 quarts of water were found by the New York Cornell station to entirely prevent new gall formation by the gall aphid on spruce.

**Airplane dusting.**—The importance of the airplane as a means of applying insecticides in dust form is increasing year by year. The Louisiana station reports its use in the application of silicofluoride dust (at the rate of 20 pounds per acre) for the control of the sugar-cane borer. A large stand of hemlocks was dusted in this way by the Wisconsin station in combating the hemlock spanworm (*Ellopia fiscellaria*), 20 pounds of calcium arsenate being applied per acre.

**Insect transmission of plant diseases.**—It was conclusively determined by experiments at the Indiana station that the spinach aphid is the principal agent in disseminating the potato leaf roll in that State, and that the potato leaf hopper is also capable of transmitting the disease but to a lesser extent. It was pointed out that the spinach aphid is also the principal insect vector in the carriage and spread of the tomato mosaic. The New York State station found the plant louse to be the vector of raspberry mosaic. Curly top was found by the South Dakota station to occur on rare occasions in the fields of the western part of that State, and it was demonstrated that noninfective beet leaf hoppers transmitted curly top from South Dakota diseased beets to healthy beet seedlings grown under greenhouse conditions in California. Potato leaf hoppers placed on alfalfa in cages at the Tennessee station caused alfalfa yellows. The peculiar yellowing of marginal areas of apple leaves commonly occurring in many orchards in the peninsular region of Wisconsin was found by the Wisconsin station to have been caused by the potato leaf hopper. Alfalfa yellows was found to have been caused by the same pest.

**Apiculture.**—In a study made of the effect of the sprays applied to fruit trees upon bees, the Massachusetts station found that any mixture containing nicotine sulphate was very repellent and fed on but sparingly, the repellent action persisting for at least 48 hours. Neither a late pink nor an early calyx arsenical spray, applied when there was considerable bloom on the trees, caused any serious mortality in colonies located in the sprayed orchard. The experiments indicated that if the recommended combination of lead arsenate, lime-sulphur, and nicotine sulphate is used the spraying should have no appreciable effect upon colonies not subject to any restrictions of flight.

Bees do not work in the field after the temperature has reached 94° F. with the humidity below 60°, according to the Texas station, which also found that under conditions obtaining in southern Texas if the queen has not oviposited by noon on the eleventh day after emergence she probably will never do so.

Balsam wool was found by the Wisconsin station to be the most effective of the insulators tested for winter protection of honeybee colonies. Wheat straw, the next best, was recommended as the proper material for beekeepers to use because of its lower cost and availability.

The foul-brood organism was found by the New Jersey stations to be destroyed by gaseous chlorine, commonly used as a water purifier.

## ANIMAL PRODUCTION

The stations made distinct progress during the year in the scientific solution of many practical problems of animal production. The work of the past year gave evidence that more attention than heretofore is being given to fundamental studies in genetics and nutrition as related to breeding and feeding of farm animals, thus furnishing a more permanent scientific basis for the improvement of practical methods.

### BEEF CATTLE

**Fasting.**—The New Hampshire station, in cooperation with the nutrition laboratory of the Carnegie Institution,

found that steers adjusted themselves more readily to fasting than to submaintenance, and there was no lack of vigor even after 14 days of fasting, but rumination practically ceased after the second day, especially in fasts following pasture feeding. As the fast progressed the animals spent more time lying down than while on feed. Changes in temperature affected the water consumption during fast; on some days no water was taken, and at other times rather large quantities were consumed. The amount of urine and feces excreted decreased as the fast progressed, but even after about 14 days' fasting there were daily excretions. Steers took several hours to consume even small amounts of feed at the first feeding following a fast.

**Roughages.**—The Oregon station has pointed out that approximately 2 pounds of alfalfa hay per 100 pounds of live weight is the daily requirement to maintain the body weight of steers. Each additional 7 to 7.5 pounds of hay produces 1 pound of gain. For maintenance purposes it required 2,100 to 2,200 pounds of barley straw, supplemented with 165 pounds of cottonseed cake or 650 pounds of alfalfa hay to equal 1 ton of alfalfa. Silage proved to have approximately 40 per cent of the value of alfalfa, pound for pound, when included in an alfalfa-hay ration for wintering stock. At the Montana station calves fed alfalfa hay made an average daily gain of 0.77 pound, as compared with 0.61 pound for calves fed bluejoint hay. It not only required more hay, but also more silage, to produce a pound of gain with the ration containing bluejoint hay. Similar results were obtained with yearlings. Alfalfa meal was markedly superior to long or cut alfalfa hay for 2-year-old steers in tests at the Idaho station. However, the cut alfalfa hay showed little advantage over the long hay. On the other hand, the Wisconsin station found that nursing cows gained slightly faster on 10 per cent less concentrates when fed cut alfalfa hay instead of long hay. There were no noticeable effects upon the calves resulting from feeding the hay in either manner.

**Pasture investigations.**—That untillable land may be profitably used as pasture was demonstrated by the California station. A field of between 35 and 40 acres in which the greater part of the roughage consisted of burr clover and alfilaria but in which bull and star thistles, wild mustard, and fireweed abounded, furnished, over a two-year period, an average of 8,244 cattle days of feed and produced 6,542 pounds of gain in weight. Grazing resulted in keeping down the foul growth. When a backward spring retarded the growth of sweet clover, the Illinois station found that adding oat straw to the ration of cows carried through the grazing season on such pasture made it possible for them to gain slightly instead of losing weight, as in the case of cows with no supplementary feed. Stump land furnished, over a period of 10 years, an average of 143 days' pasture to 7.66 head of heifers per year in an experiment at the Minnesota station. The cattle made an average daily gain of 1.14 pounds per head. The pasture season could be lengthened by day grazing. The Mississippi station found that cattle grazed on burned pastures for 224 days made a gain of 148 pounds as compared with 110 pounds on similar pasture that had not been burned. However, certain types of forage grew from 3 to 4 inches higher when protected from burning than did the forage in the burned pastures. Native pasture was found by the North Carolina station to be inferior to tame pasture for cattle. Cattle on native pasture made an average daily gain of 1.16 pounds per head, while those on tame pasture made 2.83 pounds average daily gain per head.

**Growth and finish.**—The North Carolina station found indications of darker color in meat of cattle finished on cottonseed meal compared with that of cattle finished on corn. The Texas station showed that the growth measurements which increased during fattening were primarily those of the soft parts of the body, while those which depended upon an increase in length of bone did not respond readily to heavy feeding. In fattening, the increases in width were much greater than those in height or length. Studies at the same station of the inheritance of conformation and feeding qualities in crossbred Hereford-Brahman steers and in the progeny back-crossed to Hereford bulls showed that the latter were in general intermediate between the crossbred and Hereford steers in feeding and killing qualities, but were heavier than either. The crossbreds did not gain so rapidly as Herefords, but a portion of the gain of the latter was due to larger amounts of paunch and intestine. The dressing percentage of the crossbreds was higher, though the carcass shape was less desirable for the average market.

**Breeding distinction by percentage of blood.**—The Texas station, from a study of the theoretical possibility of differentiating between animals carrying dif-

ferent percentages of Brahman blood on the basis of physical characteristics, concluded that the percentage of blood was sufficiently accurate to distinguish three-fourths-blood from seven-eighths-blood Brahmans, but not sufficiently accurate to identify animals differing by only one-sixteenth blood. Measuring relationship between two individuals by percentage of blood does not lead to serious error when one of the two individuals is a direct ancestor of the other, but the method is not suitable when individuals are collateral relatives, nor is it applicable for measuring the degree of inbreeding.

SWINE

**Methods of breeding.**—Comparing the size of litter, mortality percentages, weights, and body measurements of pigs born in matings between half brother and half sister and outcrossed individuals, the Oklahoma station found that the outcrossed individuals showed a slight advantage at birth, except in size of litter, but the differences were not significant. The limited inbreds averaged 5.2 pounds heavier at weaning, but all groups were similar in other characteristics, and surplus animals were fattened to 200 pounds with similar results in rate and economy of gain.

**Inheritance of hernia in swine.**—A study of the Wisconsin and Ohio stations' herds showed that inguinal hernia affected 1.68 and umbilical hernia 0.6 per cent of the male pigs born, while 1.16 per cent of the female pigs were herniated, practically all of which was umbilical. The results indicated that the condition of inguinal hernia was definitely inherited.

**Type.**—Representatives of the rangy and intermediate types were hand-fed and self-fed on rations of corn, middlings, tankage, and pasture at the Illinois station. A larger percentage of the intermediate pigs were finished at the 225-pound weight than of the rangy type. Cutting tests showed that there was a slightly larger percentage of fat cuts from the intermediate carcasses than from those of the rangy pigs. When self-fed there was approximately 6 per cent more fat in both types than in similar hand-fed animals. At the Iowa station the big-type pigs required the least feed per unit of gain to 300 pounds in weight, though the medium type made more rapid gains and required 30 days less time than the big type and 41 days less time than the small type to reach 250 pounds.

**Canadian field peas as feed.**—The Idaho station found that sows fed field peas had a tendency to go off feed. They also gained more slowly and required more feed per unit of gain than those fed barley. One sow fed field peas during gestation developed paralysis two weeks prior to farrowing. Pigs farrowed from sows fed peas weighed between 1.5 and 2.5 pounds, while pigs from sows fed barley weighed between 2 and 3.5 pounds at birth. When rated on vigor, most of the pigs from the barley-fed sows graded between "strong" and "very strong," while those fed peas graded from "fair" to "strong." Of the first litters farrowed by sows fed peas, 10.3 per cent were born dead, of later litters only 5.88 per cent. No dead pigs were farrowed by the barley-fed sows. Fattening pigs fed field peas made practically as rapid and economical gains as those fed barley. The bones of the pigs fed field peas were weaker than those fed barley.

**Legume hay as feed.**—In experiments at the Arkansas, Delaware, and Pennsylvania stations legume hay proved an excellent and economical feed for the winter ration of brood sows. Gilts receiving soy-bean hay with corn farrowed extra good litters as compared to one satisfactory litter from gilts fed corn and tankage. Alfalfa leaves added to a white ear corn and minerals ration supplied some essential that was evidently lacking in this ration when tankage was fed. Pigs from sows receiving the alfalfa leaves weighed 2.55 pounds at birth as compared to 2.38 pounds on the tankage ration. Of the former pigs, 40.6 per cent were classified as strong, while only 10.7 per cent of the latter were so classed.

**Vitamins for sows and pigs.**—A ration of white corn, white-corn bran, and tankage fed to brood sows and their litters at the Illinois station was found to be deficient in vitamin A, and its continued use resulted in various disturbances of gestation and pathological symptoms which were corrected by adding 1 per cent of cod-liver oil or a small amount of alfalfa leaves to the ration.

**Protein supplements.**—Studies at the Texas station indicated that sows produced as large and healthy litters when cottonseed meal was used as a protein supplement as when animal proteins were fed. Pigs on a balanced ration made good and economical gains when fed cottonseed meal; however, when fed with milo it was found bene-

ficial to supplement the meal with minerals. On the other hand, two out of five pigs fed a ration containing 25 per cent of cottonseed meal at the Ohio station died before the end of a 132-day feeding period. The remaining pigs were rough and wrinkled in appearance and gained but little. Postmortem examination of the dead pigs showed the internal fat and the outside of the hides to be extremely yellow. The Oklahoma station found that cottonseed meal was toxic when fed in large amounts or to young animals, but that the toxicity was overcome by autoclaving for one hour at 20 pounds' pressure or by cooking one hour with steam. Equal parts of meat meal and cottonseed meal produced better gains than meat meal alone in experiments at the Florida station. When cottonseed meal replaced one-half the fish meal in a fattening ration for pigs in experiments at the North Carolina station the daily gains were increased and the feed required per unit of gain decreased.

Ground soy beans, even with the addition of minerals, were found by the Delaware, Nebraska, and South Carolina stations to be inferior to tankage as a protein supplement, and stiffness and lameness were observed in some of the pigs receiving soy beans. Combinations of soy-bean oil meal and fish meal and of peanut-oil feed and fish meal produced more rapid and more economical gains than tankage. At the Iowa station a mixture of linseed meal, alfalfa meal, and tankage proved more satisfactory than tankage alone. Tankage and fourth-cutting alfalfa, equal parts of tankage and cottonseed meal, and shorts and tankage resulted in larger gains than a single animal protein at the Nebraska station. The Kansas station found that the greater the proportion of tankage and the less the proportion of linseed meal in the ration the greater were the gains, the better the finish, and the cheaper the gains.

**Curing pork.**—In studies at North Carolina the shrinkage of hams, sides, and shoulders from pigs fed a limited ration with peanut pasture was small during curing and storing. There was a large shrinkage in the same cuts from pigs on soy-bean pasture and from pigs fed in dry lot. The color, texture, taste, and rate of cure of pork are governed by the bacterial flora and ionization of the brine, the temperature of the cure, and the condition of the meat at the time of cure, according to investigations at the Iowa station. Color development during curing was found to depend on the concentration not only of nitrites but of salt. Nitrites proved effective in a concentration of one-tenth to one-twentieth that of the nitrates generally used, but a desirable color was not produced until the concentration of salt was increased to at least 10 per cent. The presence of calcium and magnesium in the water used for curing had no noticeable effect upon color formation or upon the taste or texture of the cured product.

### SHEEP

**Roughages.**—At the Illinois station it was found that 1.52 pounds of timothy hay, 1.78 pounds of clover hay, and 1.9 pounds of alfalfa hay per 100 pounds live weight when fed with 0.14 pound of linseed-oil meal were required to maintain body weight. In experiments at the Washington station second-cutting alfalfa hay cut at the three-fourths to full-bloom stage yielded the most digestible matter per acre. First-cutting hay cut at the one-half to three-fourths stages of bloom and third-cutting at the one-half stage of bloom produced the maximum yield of digestible matter per acre.

**Feeding pregnant ewes.**—In comparing alfalfa and soy-bean hay for pregnant ewes at the Illinois station, one lot received 3.12 pounds of the former and 3.77 pounds of the latter per day until lambing. The ewes refused on the average 1.7 and 15.2 per cent of the respective hays. The same kind of hay supplemented with grain was fed after lambing to both ewes and lambs. No apparent injurious effects resulted from feeding soy-bean hay to pregnant ewes and lambs. The gains made by the lambs fed soy-bean hay were as good as those in the alfalfa lot, though somewhat more hay was consumed.

**Fattening lambs.**—In experiments at the Nebraska station with corn, barley, and dried beet pulp, fed with alfalfa hay, corn proved superior to barley and barley was superior to dried beet pulp in producing gains in fattening lambs. When cottonseed cake or linseed cake was added to the ration the difference in value in favor of the corn was reduced. Cottonseed cake and linseed cake were practically equal in value when fed with the above feeds. Cull potatoes, beet tops, beet-top silage, and corn silage had approximately the same feed value when fed with corn, cottonseed cake, and alfalfa hay. They ranked in the order named in the production of gains. One ton of

beet-top silage was found to have the same feeding value as the tops from 1.6 tons of beets when the tops were piled in the field. Ear corn fed with alfalfa hay either with or without linseed-oil meal was inferior to shelled corn similarly fed. However, ear corn proved to be more efficient than ground barley in both rate and economy of gains.

**Breeding efficiency of fat ewes.**—The Oregon station found that excessive fat apparently had no detrimental effect upon the breeding efficiency of ewes, but that fattening is usually a result of nonbreeding. In ewes known to be breeders no differences were observed between those that were fattened and those kept in a medium or thin condition.

**Wool.**—The fleeces of sheep fed alfalfa hay with or without cottonseed cake, at the Montana station, were uniformly heavier than those of sheep fed mixed hay or oat straw and cottonseed cake. The fleeces produced on the latter feeds were dry, harsh, and lifeless to the touch, whereas those of sheep fed alfalfa did not show these undesirable characteristics. However, there were no variations in stretch, break, diameter, tensile strength, or elastic limit on equal areas of the different fleeces that could be attributed to differences in feed. The yolk and other factors that go to make up shrinkage were influenced by the amount of feed, but the physical properties of the wool fiber were not easily affected by the feeding. In fineness of fleece, samples taken from the shoulder, belly, and thigh of Rambouillet sheep at the Wyoming station ranked in the order named. Fine fiber averaged 1.5 more crimp per inch than coarse fiber. High-grade fleeces were found to yield 74 per cent more fibers from a given area than low-grade fleeces. It was determined that the staple length of a 12-month fleece of a Rambouillet sheep at the shoulder and thigh should be 2.33 inches.

In a study of the wool of crosses of Rambouillet ewes mated with Hampshire and Southdown rams, and Oxford ewes mated with Rambouillet rams, the New Hampshire station found that the average diameter of the wool fiber may be increased or reduced by careful selection of the parents. The variability of the length of fiber decreased in successive generations, but there seemed to be no physiological relationship between small diameter and shortness of fiber. Crimpiness showed a slight inclination of the first generation crosses toward the parent having the largest amount of crimp in the wool. There was no definite relation between the amount of crimp and the diameter of the fiber, though there was a positive correlation between the percentage of crimp and the length of fiber, probably due to the greater possible elongation of the more crimpy fiber.

## POULTRY

**Artificial light.**—The use of artificial light was found effective in increasing egg production during the winter months at the Delaware, New Jersey, and South Dakota stations. No detrimental effects followed the use of artificial lights. The cost of producing eggs was less when artificial lighting was used, and the average value per dozen eggs was greater because more eggs were laid when peak prices prevailed. Lights were of no value for stimulating egg production when the daylight increased to at least 12 hours per day.

**Feed in relation to body temperature.**—The Illinois station found that hens on a ration composed mostly of corn in amounts sufficient to support production of one egg per day could stand outdoor temperatures of 15° F. before requiring additional feed to keep the body warm, provided humidity was not high nor the birds exposed to sharp winds.

**Time of hatch.**—The New Mexico station found that chicks hatched in February and March made good growth and started laying at an early age, but went through a fall molt that cut down their production. April-hatched chicks did not go through this fall molt, and as a result gave the highest annual production and the greatest net return of groups hatched at varying periods of the year. Spring-hatched chicks were at the height of vigor and vitality during the breeding season, and also produced a greater number of eggs during the fall and winter, when prices were high. Chicks hatched in May, June, and July showed the effect of hot weather in retarded growth and maturity. August, September, and October hatches showed improvements over summer hatching, but were not as good as the spring hatch. The chicks hatched in November were slow in maturing, but had a rather high production for the year.

**Coloring egg yolks.**—Ripe pimiento peppers, dried, ground, and fed at the rate of 0.5 gram per hen per day, at the Georgia station, caused the yolk of the eggs to become a deep reddish yel-

low. Color first appeared in the yolks five days after the start of feeding. From the fifth to the tenth day there was a wide variation in color, but after that time the color became uniform. The white of the egg remained unchanged, and the color of the shell changed but little. Pimiento peppers did not change the keeping, cooking, or candling qualities of the eggs.

**Protein supplements.**—Varying amounts of raw cottonseed meal added to a laying ration gave practically uniform production in experiments at the Oklahoma station. Addition of minerals to such rations increased the rate of production and decreased the cost per dozen eggs. Processed cottonseed meal (raw meal cooked under pressure) proved more efficient than raw meal, but not as efficient as raw meal plus minerals. When raw meal was fed in small amounts a high hatchability was obtained, which decreased as the amount of raw meal increased. The effect of the processed cottonseed meal was directly opposite to that of the raw meal. When minerals were fed with the raw meal the percentage of hatchability was practically the same in the low, medium, and high cottonseed-meal lots. Twenty per cent of tankage increased the egg production from 23 to 36 eggs over the same period in a test at the South Dakota station. Hens at the Nebraska station laid an average of 101 eggs during a 212-day test when receiving buttermilk ad libitum. Another lot receiving 15 per cent meat meal averaged 112 eggs during the same period. The calculated cost per dozen was 1.3 cents less in the buttermilk lot. At the New Jersey stations, during the period from December to April, 33 hens receiving meat scrap (50 per cent protein) laid 2,516 eggs, while a similar lot receiving bone meal (25 per cent protein) laid only 1,045 eggs.

**Vitamins.**—At the California station birds showing lesions of vitamin A deficiency were cured by the addition of 1 cubic centimeter of salmon oil to the ration. Yellow and red carrots were also found to be as good sources of vitamin A as the common varieties of green feeds used, but white carrots, turnips, and mangels proved valueless as sources of vitamin A. Cod-liver oil proved slightly more valuable as a source of vitamins than lawn clippings in tests at the Idaho station, though both of these feeds gave higher production, higher hatchability, and less mortality than rations containing no green feed or dry yeast. The New York Cornell station and the Ohio station demonstrated that cod-liver oils and cod-liver meals varied significantly in their vitamin content when measured by their ability to prevent leg weakness in chickens.

**Incubation.**—The Idaho station found that a very definite relationship existed between the weights of the eggs set and the weights of the chicks hatched. Chicks from the larger eggs were heavier, and this relationship still existed at 8 weeks of age. In tests at the North Carolina station, turning eggs six times a day from setting to the eighteenth day gave an average of 16.5 per cent greater hatch of all eggs than turning once a day.

**Hatchability.**—Freezing the combs of breeding males was found to reduce their normal capacity to fertilize eggs for only 11 days in tests at the Kansas station. Studies at the Minnesota station indicated that the hatchability of eggs laid by extremely old or very young breeding stock was not as good as that of eggs from 2 or 3 year old hens. Exposure of eggs to temperatures of from 28° to 32° F. for three successive nightly periods of 14 hours each had no significant effect upon hatchability in experiments at the California station. This exposure plus a continuous exposure of 38 hours at the same temperature also had no effect. When the nightly exposures were increased to 4 and these were followed by a continuous exposure of 38 hours there was a significant reduction in the percentage of eggs hatched. The South Dakota station found that the hatching percentages with clean and wiped eggs were 83.3 and 80 per cent, respectively, but only 40 per cent of the eggs that had been washed and 16.6 per cent of dirty eggs hatched. The Massachusetts station found that the physical characteristics of eggs were of less importance in relation to the hatchability of eggs than the genetic make-up of the hen laying the eggs or the male fertilizing the eggs.

**Fertility of eggs.**—The Connecticut Storrs station found that the time elapsing between matings and the laying of the first fertilized egg averaged less than 48 hours, with a minimum of about 21 hours. The duration of fertility from a single mating averaged over 2 weeks, with a maximum of approximately one month, and there was no indication of a differential viability of the embryos resulting from the age of the sperm up to at least two weeks, nor any indication of an effect of the time between fertilization and laying on the sex of the embryos.

## DAIRYING

**Inheritance of milk-producing qualities.**—The Missouri station found, in a study of progeny performance records of Jersey sires having 10 or more daughters and of Ayrshire sires having 5 or more advanced registry daughters, that for each 100 pounds increase in the average production of fat there was an increase in the daughters' records of approximately 10 pounds of fat for the Jerseys and 20 pounds for the Ayrshires. Further studies indicated that the dam's records were a poor index of the individual's ability to transmit production qualities to her granddaughters, the sire's average progeny performance being a better indication in both breeds.

**Milk secretion.**—Experiments at the Illinois station showed that the percentage of fat in the milk was materially increased by feeding rations high in oil. Soy bean and soy-bean oil meal did not appear to produce any significant increase in the butterfat test, but flaxseed meal, peanut meal, linseed oil, and peanut oil increased the fat test. The effect of a high-oil ration appeared to be greatest within the first two or three days. A decline tended to follow this maximum stimulation. Some effect of the high-oil rations was apparent for from 12 to 36 hours after the cattle were taken off them. At the Minnesota station feeding ground flax at the rate of 3 pounds per day caused an average increase of 2.9 per cent in the fat content of milk. It also caused an average increase of 1.1 per cent in the amount of milk produced. The response to the flax feeding was almost immediate, appearing in most cases eight hours after the initial feed.

The Maine station found that not over 20 per cent of the milk obtained is secreted during milking, while the Missouri station found that 31 per cent was secreted during milking. About 0.2 pound of secreting tissue was necessary to secrete 1 pound of milk in a 15-hour period.

**Sunlight and vitamins.**—A heifer calf confined in a darkened box stall, at the Minnesota station, from 1 week to 2 years of age, continued normal in all outward respects during the test. Lack of sunlight did not impair reproduction, the heifer dropping a normal calf at 16 months of age. At the Kansas station heifers housed in a darkened shed grew at the same rate as those which had access to direct sunlight, and showed no signs of rickets. At the Pennsylvania station 11 calves fed on rations lacking vitamin B for approximately two years grew normally to maturity, and 5 conceived and dropped strong, healthy offspring. The heifers went off feed from one to three weeks after freshening, and became weak and emaciated, showing the ration to be inadequate for lactation. Milk from these heifers fed to rats on an otherwise vitamin B-free ration proved as potent a source of the vitamin as milk from cows fed on the usual winter ration.

**Succulent feeds.**—Tests at the Idaho station showed apple pomace silage to be equal to corn silage for the production of milk and butterfat. Pomace silage was very palatable, and the cows ate it readily. Feeding pomace silage just before milking caused an off flavor in the milk, but as the odor was absorbed from the air of the stable the difficulty was easily overcome by feeding the pomace silage immediately after milking. Cows fed okra, at the Georgia station, consumed 27.2 pounds more of this feed than they did of chopped sorghum, and produced 3 pounds more milk per day. No difference was noted in the color, flavor, odor, or appearance of the milk produced on these feeds. Butter made from the cream produced during okra feeding had a somewhat higher melting point.

**Grinding alfalfa hay.**—Trials at the Michigan station showed a difference of but 44.1 pounds of milk and 2.275 pounds of butterfat in favor of ground alfalfa hay, as compared to long hay, for six cows during a 20-day period. The palatability of alfalfa hay was unaffected by grinding in tests at the South Carolina station, and there was no marked effect upon the quantity or quality of the milk produced. The digestibility was practically the same for the ground and unground hay, but grinding the hay increased the cost of production. Preliminary work at the Wisconsin station indicated that grinding poor-quality alfalfa hay may show some adventages, but that grinding good-quality hay was not economical.

**Minerals.**—At the Minnesota station it was found that production appeared to be increased by the use of phosphate supplements, but there was no evidence that the ash of the milk was changed in any way. The effects of mineral deficiency were reflected in a lowered rate of reproduction and relatively infrequent ovulation. Reproduction was considerably improved by the phosphate supplement. The Wisconsin station found that the forages in certain sections of the State were low in

phosphorus content. Cattle fed these forages alone showed depraved appetites, became emaciated, and the hind quarters became stiff and the joints swollen. After three months' feeding on rations high in phosphorus, cows gained 200 pounds in weight and increased 50 per cent in milk production.

**Self-feeders.**—In trials at the Illinois station, cows tended to eat more feed than was required for maintenance and milk production when self-feeders were used. This larger consumption tended to increase body weight. No harmful effects followed self-feeding if the animals were gradually accustomed to the feed, but the cows showed a variation in their preference for feeds at different periods.

**Shrinkage in ice cream.**—Studies at the Massachusetts station showed that the shrinkage of ice cream dished from bulk averaged about one-third the original volume. The shrinkage was about the same regardless of the type of disher used, but the ice-cream spoon was found to be the most practical. Overrun had little effect upon volume shrinkage, and only extremes of dishing temperature had marked effects. The composition of the mix had less effect than the personal equation, a careful operator being able to keep shrinkage at a minimum.

**Density of ice cream.**—Experiments at the California station showed that by turning off the beater during the unloading period the variation in the density of the ice cream for consecutively drawn cans can be reduced to a minimum. When the speed of the scraper was 140 revolutions per minute or less there was little variation in the overrun, but at 211 revolutions per minute there was a very noticeable decrease in density. The higher the speed of the scraper the less variation there was in the weight of the finished product, and the shorter the time required to draw the ice cream. The principal function of the beater appeared to be in transferring heat, dividing the cells, and producing a smoother product. Increasing the speed of the beater and scraper produced an ice cream of better texture, but as the rate of speed increased the melting resistance of samples decreased.

**Shrinkage in butter.**—Investigations by the California station showed that butter cut with a worm-gear cutter lost 0.48 per cent more moisture during 13 days' storage than did butter cut with the wire-type cutter during the same storage period. At the Illinois station it was found that butter passing through printing machines in which it was crushed did not keep as well as butter not treated in this manner, and that undesirable flavors developed in such print butter. Preliminary work at the New York Cornell station indicated that the shrinkage of butter by evaporation and leakage can be largely controlled by thoroughly incorporating the moisture in the fat in the working process.

**Quality in butter.**—The Iowa station found that churning sweet cream, ripened cream, and sour cream in a carbon-dioxide atmosphere tended to lower the score of the butter, but had no influence on the composition, rate of oxidation, or bacterial count. Tests at the South Dakota station showed that butter made with a starter had a somewhat higher score when fresh and after six months' storage than butter made without a starter. Butter made from thawed frozen cream churned as rapidly as that from unfrozen cream. Butter so made showed a short grain when fresh and after storage.

Parchment paper that had been exposed to dust and contamination was shown to be a source of mold on butter in tests by the Minnesota station. This condition could be overcome by boiling the paper for 10 minutes before using. Salt may be added to the water in which the paper is boiled if desired.

**Neutralizers.**—The Arkansas and Illinois stations found that lime neutralizers were more efficient than soda neutralizers. Lime neutralizers had a tendency to cause a limy flavor, while soda neutralizers tended to produce soapy flavors. Soda ash increased the amount of fat lost in the buttermilk, while sodium bicarbonate and lime gave a more complete churning. None of the neutralizers improved the quality of the fresh butter, but when used separately they gave higher scores than when used together. Soda ash produced butter that did not stand up well under storage.

**Creaming of milk.**—The Pennsylvania station found that the temperature of the pasteurization media did not appear to affect the creaming ability unless it was higher than 212° F.

**Buttermilk.**—It was found in studies at the Iowa station that metallic flavors developed in buttermilk held in glass containers when certain combinations of starter organisms were present.

No advantage resulted from adding gelatin to buttermilk in tests at the Oklahoma station. Samples containing gelatin broke up more easily and the curd appeared softer than those

containing no gelatin. Gelatin did not prevent wheying off. The addition of 0.3 per cent gelatin gave buttermilk a slight off flavor, and the longer samples were held the more pronounced this flavor became.

**Cheese.**—The New York Cornell station found that Cheddar cheese can be successfully made from milk pasteurized at 145° F. for 30 minutes. Such cheese was of better average quality and retained more uniform quality under storage than cheese from raw milk. Under all conditions pasteurization tended to increase the yield of cheese due to the retention of more fat, moisture, and milk solids-not-fat in the curd, but especially was it advantageous when the milk was of poor quality. In experiments at the California station the texture of Cheddar cheese was not affected by pasteurizing milk of good quality by the flash method at 165°, and the flavor was slightly improved after two to three months' storage. Results of tests at the Wisconsin station indicated that American cheese curd may be pasteurized by treating with hot water (140°) to improve the flavor and texture. Pasteurization when curd acidity was high, about 0.6 per cent, gave the best results.

Adding calcium chloride to the milk previous to adding the rennet extract was found by the New York Cornell station to increase the yield of Cheddar cheese and to decrease the amount of rennet extract required without injuring the quality of the cheese.

### DISEASES OF ANIMALS

**Infectious abortion.**—This disease held its important place in the investigational work conducted, reports relating to it having been issued from no less than 13 stations. A step forward was made in the diagnosis of the disease through the perfection by the Michigan station of a rapid method of performing the agglutination test, which is as accurate as the slow method. Studies of the presence of agglutinins in milk by the California station indicate that the agglutination test of milk is not a reliable indicator of udder infection with the causative organism. The close relationship of the causative organism with that of Malta or undulant fever due to *Bacterium melitensis* and the recognition of numerous cases of undulant fever in man due to *B. abortus* has led to comparative investigations of the two organisms. The Connecticut Storrs and Michigan stations have found decided differences between the two organisms.

Particular attention was given by the stations to the protection of cattle against the disease. Vaccination with the live abortion germ at the California station gave encouraging results. Work with the living vaccine at the Minnesota station led to the conclusion that while some degree of immunity is induced it does not reduce the abortion rate to a desirable minimum and should never be used in other than badly infected herds. Experiments at the Texas station indicated that the use of live culture in no way reduced the breeding efficiency of the herd. The use of a bacterin regularly in the early fall, giving three injections at intervals of a week, prevented abortion in experiments at the Kentucky station. The intravenous administration of acriflavine was found to give promising results as a treatment for infectious abortion at the Georgia station. In tests made at the Michigan station it failed to diminish the *B. abortus* flora of the udder. In studies at the Washington station the organism was found to be resistant to temperatures from below freezing to 80° for as long as 87 days.

Several stations have reported successful elimination of this disease from herds through detection by the agglutination test, the isolation of the infected animals, and sanitary measures. The disease was eliminated from the beef herd at the Colorado station in 10½ months with five blood tests and from the dairy herd in 18½ months with eight blood tests. In Connecticut it has been eradicated from 15 herds since the work was commenced in 1925. A herd with 70 per cent of reactors was reported by the Georgia station to have been freed from the disease in less than two years without selling the reactors. Work with a clean and an infected herd at the Minnesota station kept in barns 75 feet apart and tended by the same man indicates that it is feasible for a breeder to maintain a clean and an infected herd in close proximity. Elimination of the disease from herds in this manner was also reported from the Delaware and Illinois stations.

That a type of abortion independent of *B. abortus* infection may occur, and possibly be transmitted to the cow by the sire, was indicated by the repeated isolation of *Streptococcus alpha* from aborted feti and afterbirths in a herd reported by the Illinois station, where abortion caused serious losses over a

period of several years. At the Kentucky station 11 of 22 foals autopsied during the foaling season were found infected with *B. viscosum equi.*

Studies of the infection in swine at the Missouri station led to the conclusion that the udder is the favorite and very persistent habitat of the causative organism. The swine type was found by the Illinois station to grow more luxuriantly than the cattle type. The same station found evidence that infection in an actively breeding boar may play a part in the spread of the disease.

**Hog cholera.**—In work at the Illinois station about 90 per cent of the pigs immunized at a very early age were still immune when exposed at the market age. It was pointed out that the expense of serum to immunize such pigs was less than one-half that required after weaning. Hog cholera virus was found by the Indiana station to survive but a short time in the body excretion and secretions and in blood from a cholera hog. It was found by the North Dakota station that the use of a nonvirulent virus may be responsible for the failure to develop a lasting immunity.

**Anthrax.**—The Louisiana station found that growing forage crops may carry spores from the soil on the surface of the plant and in this way infect animals which feed upon them. The spores are not easily removed from the surface of the plants by rain.

**Bacillary white diarrhea infection.**—The activity in research work with this important disease of the fowl continued unabated, particular attention having been given to the perfection of means of detection of the carrier fowl. The keeping of heavily infected fowls was shown by the North Carolina station to be uneconomical. The percentage of infected eggs was found to rise as production increased. The percentage of infected eggs laid by carrier fowls was found at the Pennsylvania station to vary considerably, the infection being entirely absent from the eggs of some carriers, while the eggs of others were infected to the extent of 35 per cent. Studies at the Virginia station of the eggs laid by 14 reacting hens showed those from 10 to be infected, the infection ranging from 2.8 to 53.9 per cent. The North Carolina station found that 7.35 per cent of the eggs laid by heavy birds and 5.25 per cent of those laid by Leghorns were infected. The necessity for using fowls free from this disease in conducting breeding and other research work with poultry was emphasized by the Kansas station. An average reduction in the fertility from 90 per cent in nonreacting hens to 70 per cent in reacting hens was an estimate made by the Texas station. The hatchability of the fertile eggs of nonreactors was placed at 70 per cent and of reactors at 58, the livability for nonreactors at 90 per cent and for reactors at 50.

In a study of the possible transmission of the causative organism by the grown fowl other than through the egg, the Indiana station found that day-old chicks failed to become infected when given feed containing droppings from infected hens, indicating that the spread of the disease among grown fowls in this way is of minor importance. The North Carolina station concludes that the chances of transmitting the disease from adult to adult are remote, provided the ground has not been previously occupied by infected chicks. This station found intermittent reactors to the agglutination test which continued to lay infected eggs while failing to react. The California station also reports finding intermittent reactors. The causative organism was found by the Wisconsin station to be quite commonly present in the intestinal tract of hens that appeared normal, but such hens do not appear to be an important source of chick infection.

Progress in perfecting the method of conducting the agglutination test was reported by the California, Illinois, Indiana, Kansas, Kentucky, Michigan, New Hampshire, North Carolina, Pennsylvania, Rhode Island, and Virginia stations.

In breeding for resistance at the Illinois station 55 per cent of the chicks from selected stock survived after inoculation with the causative organism, while only 10 per cent of the chicks from unselected stock survived.

**Fowl typhoid.**—The causative organisms of fowl typhoid and of bacillary white diarrhea have been shown by investigations at several stations to be very closely related. Studies of the resistance of the fowl typhoid organism in soil at the New Jersey stations showed that it will succumb within a week from an acidity of pH 6.2 or lower, but will survive for 16 weeks in a soil acidity of pH 7. Evidence was obtained by the California station that the infection is transmitted through the eggs of infected hens, as indicated by work at the New Jersey stations.

**Fowl pox.**—The Oregon station has shown that immunization of young fowls by the use of an active virus will satisfactorily control this disease. Fowls vaccinated with an active virus when 4 months of age were immune 11 months later. Immunity to comb vaccination was found to follow leg vaccination, and immunity to leg vaccination to follow comb vaccination. The use of autogenous bacterins for fowl pox, administered in the early stages of the disease, caused general improvement in the health of birds at the Massachusetts station. A vaccine prepared by mixing finely ground fresh tissue obtained from cockerels with pronounced comb infection of chicken pox with a suitable liquid diluent was used with success at the California station. It was found that flocks of healthy young fowls from 4 to 7 months of age could be vaccinated and protected against subsequent infection without danger of inducing harmful chicken-pox infection among them. In such cases all the susceptible fowls on the premises must be vaccinated. It was found that the vaccine may be administered to fowls in flocks in which an outbreak of chicken pox exists without increasing the severity of the lesions of fowls already infected or hastening the spread of the infection among healthy fowls.

**Avian tuberculosis.**—The rate of transmission of the avian form of tuberculosis to calves was found by the Illinois station to be very low even when the calves were exposed to tubercular chickens, indicating that the danger of spread by this means from calf to calf is very slight. The progressive bovine type of the organism only occasionally produced lesions when fed and injected into healthy chickens.

**Coccidiosis and paralysis of the fowl.**—That one form of paralysis in the fowl may be caused by the presence of coccidia in the duodenum was determined by studies at the Michigan station.

**Blackhead of turkeys.**—The Missouri station has developed a method of abligation or tying off of the cecal pouches which promises to be a satisfactory means of combating blackhead in turkeys.

**Roundworms.**—It was found by the Nebraska station that the infestation of pigs by ascarids can not be determined by a blood test and that the resistance acquired by pigs to such infestation is due to age and not to an immunity. The possibility that rodents may act as intermediary hosts of ascarids was indicated, although this method of infection does not commonly take place in nature.

Chickens whose diet was deficient in vitamin B were found by the Kansas station to be much less resistant to attacks of the large roundworm than were those whose diet was well supplied with it. Eggs of this parasite buried from 2 to 4 inches beneath the surface of the soil were found to be killed by the heat from the sun in unshaded soil during the period July 21 to August 20. Many of the eggs placed similarly in shaded soil, however, survived. Embryonated eggs placed on the surface of the soil were killed by a temperature of —20° F., but burial at a depth of 4 inches gave sufficient protection to enable large numbers to survive. In experiments at the Illinois station in which eggs of various intestinal parasites were buried just beneath the surface of the soil in an open field no roundworm eggs were found after 8 months, no eggs of the whipworm of swine after 4 months, and no eggs of the lungworm of swine after 5 months, but eggs of the cecal worm of poultry buried August 10, 1926, were in normal condition 8 months later.

Iodine vermicide pills containing 0.4 gram of adsorbed iodine were found by the Michigan station to be 100 per cent efficient in the treatment of ascarid and hookworm infestations in silver foxes, except in cases where a heavy ascarid infestation occurred.

The earlier findings of the Kansas station that pigs may disseminate the hookworm of man, the eggs passing unharmed through the digestive tract of the pig and hatching in the feces, was confirmed by the Porto Rico station.

**Manson's eye worm of poultry.**—The Florida station and an Australian investigator working independently found that the cockroach is responsible for the transmission of the eye worm of chickens and ducks. The cockroach ingests the young larvae from the droppings and from the ground, the larvae then passing through the wall of the intestines and encapsulating. The cockroaches are fed upon and the fowl infested in this way.

### FOODS AND HUMAN NUTRITION

**Bread from soft-wheat flour.**—The Missouri station obtained good results in making bread from soft-wheat flour with the use of only a small amount of liquid yeast and the addition of potato water or buttermilk as the rest of the

liquid. The best loaf was obtained with potato as the source of gelatinized starch for the starter and potato water as the liquid. Corn sirup did not give as good results as cane sugar. Excellent bread was obtained with apple and apple water with the liquid yeast. The bread thus made had a fine silky texture, excellent volume, and kept fresh longer than any of the other breads made from the soft-wheat flour. Recipes using liquid yeast have been worked out. Satisfactory recipes have also been prepared by the Illinois station for the use of soft-wheat flour in short-process and long-process bread, Parker House and luncheon rolls, and coffee bread.

**Spoilage in canning.**—In experiments at the Florida station spoilage occurred in peas canned by the hot-pack method, heating for 3 hours in a water bath, or at 10 pounds' pressure for 50 minutes, but did not occur in corn canned in the same way. It is suggested that this may have been due to the fact that the corn was more loosely packed in the containers, thus facilitating heat penetration and more thorough sterilization.

**Discoloration of canned products.**—The Illinois station found that the black discoloration of canned corn, due to iron sulphide, increased with the protein content of the corn and decreased with the weight of tin in the coating of the cans. Brown coloration, due to tin sulphide, increased with the protein content of the corn and with the weight of the tin coating of the cans. It is suggested that the development of low protein strains of corn may be a means of avoiding both kinds of discoloration. Discoloration of cranberry sauce preserved in lacquered tin cans was traced by the Massachusetts station to the reaction of the coloring matter in the cranberry with iron dissolved from the inner surface of the can along the seams.

**Pectin and jelly making.**—Results of investigations at the Delaware station indicated that the jellying power of a pectin solution may be expressed by its viscosity. Factors affecting the viscosity include the H-ion concentration of the solution, the concentration of pectin in the solution, the method of precipitating the pectin with alcohol, the temperature of drying, and the time of standing at different temperatures. A method based upon these factors has been developed for the preparation of a high-quality pectin. Unsuccessful efforts by the Florida station to prepare a standard jelly from kumquats, although the pectin content, 1.688 per cent, and the H-ion concentration, pH 2.9, were supposedly satisfactory, led to an attempt to prepare pectin from kumquats by the electrodialysis method. Relatively pure pectin was obtained in this way.

**Use of fruits in ice cream, water ices, and frozen specialties.**—Standardized formulas have been developed at the California station for the utilization of fresh fruits and fruit products in the manufacture of ice cream, water ices, and frozen specialties. Among the fruits, not heretofore used to any extent commercially for ice cream, which gave good results were figs, persimmons, avocados, dried prunes, and Muscat raisins. The lowest and cheapest grade of commercially canned fruits, the solid-pack pie grade, proved most satisfactory for use in ice creams and ices. Bottled juices of some fruits proved satisfactory for fruit water ices, but in general fruit concentrates and sirups were not satisfactory.

**Vitamin content of foods.**—The Michigan station found leaf lettuce to be much richer in vitamin A than head lettuce, and the outer leaves of head lettuce considerably richer than the inner. Leaf lettuce grown in the hothouses and out of doors showed no appreciable differences in vitamin A content.

The vitamin C content of a cow's ration has little if any influence on the vitamin C content of its milk, according to evidence obtained at the Kansas station. When fed to guinea pigs in 30-cubic centimeter daily amounts the milk of cows stall-fed on a grain mixture, alfalfa hay, and corn silage with no green feed proved as effective an antiscorbutic as the milk of cows on pasture and thus receiving green feed and sunshine.

In a study of the vitamin B content of corn products used as animal feeds and for human food, the Illinois station found that whole corn, corn germs, and those corn products which include corn germs, such as corn-germ meal, gluten feed, hominy feed, and whole ground corn meal retaining germs, contain considerable amounts of vitamin B. On the other hand, corn products consisting largely of endosperm or hulls, and containing little or no germs, such as hominy in its various forms, the various grades of corn meal not containing germs, corn flour, crude and refined corn oils, cornstarch, grits, gluten, hulls, steep water, and corn flakes seemed to be relatively poor sources of this vitamin. The amounts present depended largely on the proportions of the germ left in the mill-

ing process. There may be some destruction of vitamin B in pop corn as a result of heating. The greatest concentration of vitamin B in the rice kernel was found by the Illinois station to be in the embryo end, although not all of the vitamin appeared to be there. It is suggested that this concentration of vitamin B in the endosperm end of the kernel may be due to its presence in the bran, which is retained in unpolished rice, rather than in the endosperm itself.

Turnip greens are an excellent source of vitamins A and B and a good source of vitamin C, according to the Alabama station. Cooking caused a slight loss in vitamin B but no loss in vitamin A. Raw collards contained slightly less vitamin B than raw turnip greens, and there was a greater loss in cooking owing to the longer time required. Collards were found to be nearly as rich in vitamin A as turnip greens, and there was no apparent loss of the vitamin in cooking. Collards were apparently richer than turnip greens in vitamin C, and there was considerable loss of the vitamin in cooking. The South Dakota station found that there was considerable destruction of vitamin C in spinach in blanching for 15 minutes in steam, as is the practice in the usual method of canning. The losses of vitamin B in string beans cooked in various ways were found by the Wisconsin station to be greatest when the beans were cooked in large amounts of water and smallest when cooked in the pressure cooker, with intermediate losses when cooked in small amounts of water and in steam. There was some loss of vitamin B in cauliflower when cooked by the steam process, the steam being allowed to escape for 5 minutes and then confined in the vessel for the next 10 minutes. When a large amount of water was used the loss was about 30 per cent.

The vitamin A content of evaporated milk made by the commercial vacuum and aeration processes was found by the Pennsylvania station to be slightly lower than that of the raw milk from which it was made. Aeration and sterilization increased the destructive effect to some extent.

Mixing lard or vegetable-oil compound with a source of vitamin E, such as wheat embryo, was found by the California station to render the vitamin ineffective, possibly through solution of it in the fat and its removal from the body with the unabsorbed fraction. The Pennsylvania station has shown that butterfat as a source of vitamin A is likewise rendered ineffective when dissolved in mineral oil, and a similar explanation has been suggested for the loss of this vitamin. No evidence was obtained of a similar effect of mineral oil on vitamin D.

**Composite character of vitamin B.**—Previous observations at the Indiana station and elsewhere that vitamin B is composed of at least two factors have been confirmed by the Alabama station, and in addition it has been shown that neither of these factors alone is growth-promoting, but each must be supplemented by the other for this effect. One of the factors is apparently identical with the antineuritic vitamin and the other may be identical with the factor considered by some to be responsible for the prevention of pellagra. Velvet beans and soy beans were found to be richer in the antineuritic vitamin, which is not stable to heat, and velvet-bean leaves and rape leaves richer in the other factor, which is relatively stable to heat. Leaves and seeds thus appear to supplement each other with respect to the growth-promoting properties of what has hitherto been known as vitamin B.

**Vitamin requirements for reproduction and lactation.**—The Arkansas station has found that larger amounts of vitamin E are necessary for successful lactation in rats than for preventing sterility, and larger amounts of vitamin B for lactation than for growth. It was more effective to give some of the vitamin B directly to the young than to administer it entirely to the mother. A highly concentrated extract of vitamin B was found to be ineffective when administered to a nursing rat in 500-milligram daily doses, but when the mother received 50 milligrams and the young 450 milligrams daily growth and development of the young were entirely successful. These results are thought to suggest the possibility that a large proportion of the infant mortality associated with gastrointestinal disturbances may be due to vitamin B deficiency, caused not entirely by deficiency of the mother's diet in vitamin B, but partly by her inability to transfer the vitamin B of her diet into the milk.

**Food value and economy of cuts of meat.**—The Illinois station found in experiments with rats that beef liver, heart, and kidney, when fed to the extent of 8 per cent of the diet, had biological values equal to or slightly higher than those of muscle meats, but lower than those of milk proteins. When fed at a 16 per cent rate liver protein was

found to have a distinctly lower biological value than when fed at the 8 per cent rate. This confirms the conclusion drawn from earlier studies that the utilization of protein (nitrogen) varies inversely with the rate at which it is fed as measured by the protein of the ration. It was also demonstrated that the more fibrous the cut of meat the lower is the biological value of its protein. Various cuts of pork were found not to differ greatly in their content of connective tissue, while those of veal and beef varied widely, the cheaper cuts containing much more than the more expensive cuts. This suggests that the cheaper cuts of beef may not be the most economical from the standpoint of utilizable protein.

On the basis of relative prices and percentages of lean meat, fat, skin, and bone in various cuts of butcher hogs fed to weights of 225 pounds each, the Illinois station concludes that neck bones, sausage, spareribs, and Boston and picnic cuts are much more economical than ham, loin, and belly as sources of lean meat and of total edible meat. Scales have been devised for the rapid calculation of cost per pound of lean meat and of total edible meat (lean and fat) in the different cuts at different prices.

**Methods of cooking beef.**—The Missouri station found that roasting beef, without searing, at temperatures of 230° and 320° F. was very satisfactory, except that these lower temperatures did not give the roast a particularly desirable appearance on account of lack of browning. The method recommended for rib roasts is roasting without searing at 320° until done, 17 minutes per pound being allowed for a medium-done roast.

**High protein diets.**—Further experiments at the Connecticut State station confirm previous observations that rats are capable of growing to adult size at an essentially normal rate on diets extremely rich in protein. In some of the successful experiments the protein (casein or meat residue) constituted two-thirds or more of the entire calorie intake. It has also been demonstrated that animals raised to large size on fairly low protein diets can become adjusted to the protein-rich diets. As noted in earlier studies, enlargement of the kidney (but with no pathological changes) was a characteristic outcome of the high protein diet, the change taking place very rapidly and with all of the proteins tested. Ingestion of considerable amounts of urea or of inorganic salts normally excreted by the kidneys failed to bring about any renal enlargement. The Iowa station has reached the tentative conclusion that the addition of meat to the diet of rats, provided enough vitamins and mineral salts are present, speeds up growth and reproduction and makes for an optimum rearing of young.

**Energy value of milk.**—From a study of the relation of the composition of milk to its energy value, the Illinois station has developed formulas for computing the heat of combustion of milk in calories per quart from (1) the percentage of fats only, (2) the percentages of fat, protein, and sugar, and (3) the percentages of fat, protein, sugar, and total solids and the specific gravity.

**Food value of pasteurized milk.**—In experiments with rats fed pasteurized and unpasteurized milk, supplemented in each case after a few weeks with yeast tablets and cod-liver oil, the Illinois station found no evidence that pasteurization lowered the food value of milk.

**Testing cow's milk for infant feeding.**—A simple household test has been devised at the Utah station for determining whether a sample of cow's milk is suitable for infant feeding in so far as the nature of the curd is concerned. The test consists in coagulating under prescribed conditions a sample of the milk with a pepsin-calcium chloride mixture and squeezing the curd through cheesecloth. The curd from soft-curded milk suitable for infant feeding passes readily through the cheesecloth, while that from hard-curded milk forms a hard lump.

**Availability of calcium and phosphorus in fresh, dried, and condensed milk.**—In experiments at the Kansas station with adults and children on diets in which as large a proportion as possible of the calcium was furnished by milk in amounts less than the optimum the retention of calcium by children was only from 50 to 75 per cent as much on the dried milk and less than 50 per cent as much on the condensed milk as on the fresh. With the adults the retention was much less on the dried milk than on the fresh milk. The general trend for phosphorus was about the same as for calcium, although the results were not as conclusive.

**Iron in nutrition.**—In experiments at the Wisconsin station the iron content of the milk of cows and of goats was not increased by feeding large amounts

of iron in easily available form. The results indicate that the percentage of iron in milk is fixed for any specific animal and can not be varied even by drastic changes in the iron content of its diet. The ash of materials such as lettuce and cabbage was found to be as effective as the fresh material in preventing anemia in rabbits on a whole milk diet supplemented with iron oxide, suggesting that the preventive factor is of inorganic rather than organic character.

**Diet and health of children.**—A preliminary survey by the Florida station of the nutritional status of 500 rural school children of two counties showed that 50 per cent of the children examined were from 5 to 33 per cent underweight, 48 per cent had defective teeth, and 33 per cent enlarged tonsils. Further examination showed conjunctivitis, skin eruptions, anemia, and hookworm to be prevalent. In a survey of the dietary habits and general state of nutrition of rural children (including 115 white preschool children, 462 white school children, and 323 negro school children) in several counties of the State, the Virginia station found the diets of over half of the children examined to be questionable, and a smaller percentage to be decidedly poor in respect to the protective foods—milk, fruit, and vegetables. The teeth were judged perfect in only 41 per cent of the preschool children examined, in 15 per cent of the white school children, and in 40 per cent of the negro school children.

In a comparative study of the food consumption of children in private homes and in an orphanage the Ohio station found a higher proportion of the protein from animal than vegetable sources, a lower proportion of the total calories from carbohydrates, and more adequate amounts of calcium, phosphorus, and iron in the diets of the children from private homes than from the institution. The chief source of calcium and phosphorus in the diet was milk, with cereals ranking next in importance for phosphorus. Cereals and vegetables appeared to be the principal sources of iron, with milk and fruits providing smaller amounts. In the case of the private home children meat and eggs were important sources of iron. A further study of eight of the children who were markedly in advance of standards of height and weight for age showed that their total consumption of food was larger than that of the other children of the same age groups, and that this was also true of protein, phosphorus, calcium, and iron. It is suggested that the diet of the institution group might have been improved by the substitution of entire cereals for highly milled ones.

## AGRICULTURAL ENGINEERING

The station work in agricultural engineering continued to show progress during the year and made some significant contributions to the attainment of greater economy in agricultural production.

### MACHINERY

**Traction.**—In field experiments made to verify the results of laboratory studies the Alabama station found that spade lugs are superior to angle lugs in loose sand when the tractor wheel carries a relatively high unit weight. Lugs which penetrate easily are superior on wheels carrying light loads. The drawbar pull, horsepower, and rolling resistance vary directly with the depth of lug, and traction is influenced primarily by the weight per inch of wheel rim width where the lugs and rim take full benefit of the arch action of the soil. The depth of angle lugs should be proportional to the square of the wheel diameter, and their proper spacing depends upon the degree of arch action of the soil.

**Tractors.**—The California station found that with one exception the radiator-fan-type air cleaners for tractor engines tested showed rather low efficiency. The vacuum or restriction effects were low and were unaffected by dust accumulation except in two cases.

The force of inertia due to the sudden starting of a wheel-type farm tractor may, under certain conditions, be very large and unfavorably influence its stability, according to the California station. Thus for stability in operation the lines of action of the load resistance and of the soil reactions against the drivewheels should coincide and pass through the center of gravity of the tractor. Under usual operating conditions raising the point of hitch to the implement, shortening the hitch, lowering the point of hitch to the tractor, or moving this point to the rear increase the potential stability of the tractor. For level-ground operation the center of gravity of the tractor should be low with respect to the rear axle, and for operation on grades it should be low with respect to the ground surface. The greatest clearance for a given position

of center of gravity or the lowest position of the center of gravity for a given clearance is obtained with the material of the tractor spread evenly over its entire width and length, with the least possible vertical thickness. From the standpoint of maximum stability and tractive ability the tractor wheel base should be as long as possible consistent with satisfactory turning. A cross grade, side draft, or an offset drawbar or combination thereof tends to decrease the tractive ability of a tractor, but increasing the width of the tractor decreases these effects. The gear ratio, engine torque, and hitch adjustment of a tractor should be such that when operating under average conditions the tractive ability will be the factor which limits the maximum drawbar pull.

**Threshers and harvesters.**—A considerable loss was found by the Illinois station where soy beans were cut as high as 6 inches above the ground. Weeds caused some trouble, especially if they were tall and the soy beans short. The bar type of cylinder met the difficulty with bull nettles better than the tooth cylinder. It was necessary to reduce the cylinder speed to about one-half that used for threshing small grain to prevent the splitting of the soy beans. The cost of harvesting soy beans with the combine was about one-third of that with ordinary methods.

Root cutting of grain sorghum plants preparatory to harvesting with a combine was found by the California station to have many advantages over ordinary harvesting systems. This was accomplished by use of heavy horizontal blades attached to a heavy orchard cultivator and running beneath the crowns of the plants.

The costs per bushel for harvesting and threshing grain were found by the Texas, Kansas, Nebraska, Montana, and Oklahoma stations to average 14 cents when using combines, 23 cents with headers, and 29 cents with binders. The 20-foot combines had the lowest fuel consumption per acre and the 12-foot machines the highest.

In studies of equipment for handling grain in bulk and in sack the California station found that combine labor cost per acre for sacked grain was $1.57 and for bulked grain 58 cents. The Oklahoma station found the grain tank to be economical when the threshed grain was hauled in trucks.

**Grain and feed grinders.**—For fine grinding of feeds the hammer mill ranks first, followed in order by the burr and roller mills, according to the Oregon station. Tests of coarse, fine, and crowfoot burrs showed that the fine burrs gave greater capacity in a stover mill for the same degree of fineness than the crowfoot burrs and required considerably less power. Increasing the speed of the mill resulted in proportional increases in capacity and a reduction in power requirement. In all mills, regardless of type, the most power was required for grinding oats, followed in order by that for barley, wheat, and corn. The Indiana station showed that in dairy feed grinding, in which definite grades of fineness were established for crushed or cracked grain, medium ground grain, and pulverized grain, both the power and labor requirements were more than seven times as great for producing pulverized corn as for producing cracked corn.

**Tillage and cultivating machinery.**—Organic matter decreases the resistance of soil to shearing or cutting, but does not reduce plow draft, although it increases the proportion of coarse granular material as much as 50 per cent, according to the Nebraska station. Lime slightly reduced plow draft, considerably reduced the shearing or cutting resistance, and reduced the toughness of the soil when wet and its hardness when dry. The stability of the soil granules was considerably improved when both lime and organic matter were added. Lime alone improved the friability of soil, and lime with manure or manure alone considerably increased the pore space and rendered the soil ideally friable.

The Illinois station found that the tractor-hours, man-hours, and fuel used per acre were all considerably less when using the 4-row cultivator for corn than when using the 2-row cultivator.

**Planting machinery.**—Striking results in favor of the 4-row planter, as compared with the 2-row planter, were obtained by the Illinois station, indicating a considerable saving in time as well as in labor.

**Spraying machinery.**—It was found by the Washington station that with higher pressures in stationary spray plants the percentage of large drops in the spray increased with the distance traveled. There was also a decided tendency for the area covered to consistently increase as the higher pressures were used, and the time required for spraying was much less than with the lower pressures. A greater degree of atomization was produced with the higher pressures, and the mist and

small drops were carried much farther. It was found possible by the California station to combine the advantages of portable and stationary spray plants by piping sections of the orchard that would be benefited and using the portable sprayer for supply and power. The portable outfit thus becomes the pumping station for the permanent piping system, and at other times is available for spraying parts of the orchard where there is no pipe line.

**Dairy machinery.**—A saving of 16 per cent in the cost of power may be expected in the operation of a refrigeration machine of medium size under normal conditions when the head pressure is maintained at 150 pounds per square inch instead of 200 pounds, according to the California station. The proper balancing of such equipment as churns was found to reduce strains in the motor and driving mechanism and to result in more economical operation. A large variation was found in the power consumption of different types of ice-cream freezers as well as with various methods of freezing and kinds of ice cream manufactured. No definite size of motor can therefore be recommended for all conditions.

Electrically heated dairy sterilizers were shown to be practical and economical if properly designed and operated, and should be safe to operate with small amounts of water. For best results the sterilizer should be insulated with a double-walled air space and be equipped with a reliable thermostat or time switch. It was also found that an electric sterilizer should be compact and made of material of low specific heat. The most satisfactory size of heater for a 4-can sterilizer is a 5-kilowatt unit. Satisfactory bacterial reduction is obtainable if the sterilizer is heated to 210° F. and held at this temperature for 20 minutes. Heating elements should be of low wattage per unit area in order to prevent their burning out if the water is boiled away. Satisfactory bacterial reduction in milk cans was also obtained by the use of temperatures of 230° F. or above for 30 minutes in small 4-can capacity dry-air sterilizers, provided good air circulation was obtained in the sterilizer. It was found that the most efficient location for the heater is in the center of the bottom of the sterilizer. The use of baffles directly over the heating elements was found desirable to prevent localized overheating and to assist in the formation and direction of convection currents. A 2-kilowatt heater was indicated as the right size for a 4-can sterilizer.

**Orchard heaters.**—Too high a burning rate in orchard heaters was found by the California station to be undesirable, since it increases the smoke and losses of heat by radiation. From the standpoint of heat distribution and smoke reduction, it is better to light all the heaters in an orchard at once and burn them at a low rate, with frequent regulation. With briquet heaters the most practical control is secured by starting with a relatively small fuel charge and by refueling at about 2-hour intervals during the night. High upward velocities and high temperatures were found to waste fuel by sending the hot gases to high levels above the orchard. Smoke has little or no benefit as a blanket to prevent radiation. Oils were found to be more effective than solid fuels.

## STRUCTURES

**Poultry house heating, lighting, and ventilation.**—No correlation could be found between air supply and egg production, fertility, and hatchability, according to the Iowa station. While the moisture conditions were very bad in houses receiving small amounts of air, the hens appeared contented and maintained egg production equal to that of those receiving large amounts of air and a slightly greater production than hens on the farm under normal conditions.

The use of brooder stoves in poultry houses was found by the Indiana station to reduce the variation in inside temperature approximately 10° and in extremely cold weather maintained a temperature 20° higher than the outside temperature. The ineffectiveness of poultry-house ventilators as commonly designed for partially open-front houses was also demonstrated.

**Barns.**—The Michigan station found that when built on Shawver truss frames the sprung-rafter Gothic roof is very rigid, and, since the rafters are supported near their middle, there is less liability of the roof becoming uneven as compared with the self-supporting frame. It was found to be good practice to use two-thirds or three-fourths of the width of the barn as the radius of rafter curvature and to locate the center of the arc about 3 feet below the top of the plate.

A certain definite amount of air flow through a dairy stable was shown by the New York Cornell station to be necessary to prevent the walls and ceiling from becoming wet. It was

found in this connection that with the Rutherford system of ventilation there is not quite the degree of mixing of air and a greater tendency of direct air flow from intake to outtake than with the King system. The Rutherford system is therefore more sensitive to weather changes than the King system. A modification of the King system was developed which differs in the placing of intakes and outtakes both in the side walls of the stable and in directing the incoming air. This permits the incoming air from either side to reach the further side of the stable.

**Silos.**—The Montana station found that sunflower silage when compacted weighs from one and one-half to three times as much as corn silage. The lateral pressure of sunflower silage on silo walls is also much greater than that of corn silage and for tall silos is more than twice as great. The deductions are that a silo of any given dimensions will hold from one and one-half to three times as much sunflower silage by weight as it will corn silage, and the hoops or reinforcing should therefore be nearly double those used in building a corn silage silo.

In the construction of a trench silo the North Dakota station found good drainage to be essential and that sloping sides and ends result in less caving, easier excavation, and less side spoilage of the silage. Greater stability is also afforded permanent walls of masonry or wood. Narrow trenches are more satisfactory than wide ones and the most satisfactory depth is about 8 feet. The depth times the average width should not make a larger end surface than will permit feeding a slice off the end every 2.5 days. Six feet of length of trench should be allowed for every month the silage is to be fed to prevent spoilage. Concrete floors have been found of no special advantage where good drainage is already available.

**Fruit storages.**—The Indiana station found that the cost of artificial cooling of apple storages, including ice and electric-fan operation, was 24.4 cents per bushel for 1,200 bushels of apples over a period of two months. Grimes and Jonathan apples kept in the iced room remained in salable condition about one month longer than similar fruit kept in uniced rooms.

Insulation is of first importance in the construction of fruit storages not only to prevent freezing in severe weather but to maintain a proper low temperature in warm weather, according to the Pennsylvania station. Air spaces are relatively inefficient as insulators, being of value only when air-tight and comparatively small. In general, masonry of all types is also a poor insulator. The following materials in the thickness given have approximately the same insulating value: Cork, 1 inch; shavings, 1⅜ inches; wood, 3⅛ inches; brick, 16½ inches; hollow tile, 16½ inches; and concrete, 26½ inches. Shavings are better for wall insulation than sawdust. The only openings into the storage should be the doors, and windows should be omitted.

**Household refrigerators.**—Insulation was found by the Indiana station to permit a refrigerator to maintain lower temperatures in the food compartments with a smaller consumption of ice. The temperature in the food chamber was found to depend largely on the amount of ice kept in the ice chamber. It rose rapidly when the ice chamber was only half full, but remained fairly uniform when the ice chamber was kept well filled. The food compartment immediately below the cold-air drop of the ice chamber was always cooler than the food compartment of the top shelf. This difference was sufficient to make an appreciable difference in the keeping of some foods.

**Adobe structures.**—The California station pointed out that low height, wide space adobe structures minimize the damaging effect of earthquake oscillations. A substantial one-piece foundation is necessary and is best provided by monolithic concrete laid on a dense subgrade. One-story construction exterior walls should be not less than 12 inches thick and nonbearing partition walls 8 inches thick. For two-story construction these thicknesses may be used for the second-story walls, and thicknesses of 18 and 12 inches should be the minimum for the exterior and interior walls, respectively, of the first story. Integral reinforcement of the exterior walls is advisable. Adobe-brick interior walls should be mounted on a foundation integral with the exterior wall foundation and should be reinforced. Partition walls of materials other than adobe should be of light construction to avoid such rigidity as might crush the adobe bearing walls during distortion. A continuous reinforced concrete bond stone of 6 inches minimum depth should be placed at the top of all adobe walls. Only compression loads should be imparted to adobe bearing walls.

**Dairy barn floors.**—The Iowa station found that concrete and rubber blocks showed the least wear as stall-floor materials of a number of materials tested, including bituminous concrete, creosote wood block, cork brick, and homemade wood blocks.

### IRRIGATION

**Soil moisture losses.**—The California station found that as a general rule a considerable quantity of water is lost by deep percolation in areas served by cheap gravity water. Contour irrigation is the best method of application when straight-furrow irrigation causes washing and when the soil is shallow and irregular. This method has been found to increase percolation and to conserve storm water. Evaporation losses were found to be extremely small portions of the total amounts of water lost from the soil. The direct evaporation losses were confined mainly to the shallow depths of soil, and moisture below the upper 8 inches was lost at an extremely low rate. The losses of moisture from the surfaces of soils exposed to evaporation for much longer periods of time than are usual between irrigations were insufficient to prohibit the growth to maturity of barley and vetch plants. Cultivation did not influence evaporation losses from the bare surfaces of field soils and did not materially influence the distribution of moisture in them.

**Soil moisture movement.**—The California station found that when soils are not in contact with free water capillary movement is extremely slow in rate and slight in amount. In sandy loams and loams no water is drawn to the surface by capillary movement from a water table 10 feet or more below the surface. A point or zone of maximum water content was found to occur at an appreciable distance above the water table. When water was free to move downward through the soil a definite minimum proportion was found to be held in such a condition that it is not free to move upward by capillarity, but is, nevertheless, readily available to plants. Water storage beyond this normal capacity can not result from winter irrigation or from excessive quantities of water applied early in the season unless an impervious layer produces a saturation zone.

The Idaho station established a definite relation between the depth of water absorbed by a soil and the time during which the water stands on the soil surface. Planting with sweet clover and repeated leaching was found to improve the infiltration conditions in alkali soils which were not extremely imperious and had satisfactory underdrainage.

### DRAINAGE

**Tile depth and spacing.**—The Illinois station found that, in tight clay soils, laterals were quite effective in lowering the ground water table when spaced 66 feet apart but when spaced 132 feet apart were not effective midway between the tile lines.

As a factor in drain design the velocity of flowing underground water varies as the square of the effective diameter of the soil grain, according to the Minnesota station. A spacing of drains of from 80 to 100 feet is usually sufficient to drain a silt soil having an average effective diameter of soil grain of 0.05 millimeter. Drains spaced from 8,000 to 10,000 feet apart should be sufficient to drain medium sand soil having an average effective grain size of 0.5 millimeter. Lateral spacing of 160 feet was found necessary where the subsoil was silt or silt loam, while with a medium sand subsoil a spacing of one-quarter mile was sufficient.

**Drainage pumping.**—According to the California station, effective drainage of soil can be obtained for a distance of more than 1,000 feet from the pump, but the pump must be kept in continuous operation in order to maintain a constant depth of water table. A rapid movement of water was found to occur through water bearing sands and gravels. It is considered likely that pumps of large capacity can be used without creating an uneconomical lift or bringing about a significant diminution of the water supply under the conditions which occur in the San Joaquin Valley.

### CROP DRYING

**Grain drying.**—No advantage was indicated in using temperatures higher than 150° F. for corn drying in experiments at the Illinois station. From the standpoint of seed-corn germination it appeared best to keep the drying temperatures 10° or more below 125° for best results. The most economical drying temperature was found to depend upon the design of the drying plant, the kind of fuel and power used, and the relative costs of fuel and power.

**Hay drying.**—The Indiana station developed successful hay-drying equipment in which the hot gases of com-

bustion are mixed with the air blown into the stack. The stacks are built over a conical pole frame and an air trench 18 inches square leads into the center of the cone. The necessity for evenness in building the stack, permitting the easy passage of air to all parts, was indicated.

**Vegetable drying.**—A temperature of 160° F. was found by the California station to be about the highest safe temperature for use in the dehydration of carrots and peas, while for cabbage it should not exceed 150°. Air velocities in excess of 500 feet per minute were found to slightly increase the rates of drying but tended to injure the products. An air flow of 500 feet per minute at a temperature of 160° gave the most economical use of heat.

### USE OF ELECTRICITY

**Water heaters for poultry.**—The Oregon station reported that drinking water for poultry may be conveniently heated with several types of simple electric heater at a cost about the same as for lighting two electric lamps. Heaters of from 75 to 100 watts capacity were found to be about sufficient for warming 2 gallons of water. In case of emergency a hermetically sealed soldering iron makes an excellent water heater. Electric lamps may be used if they are supported close to the underside of the pan and both the pan and lamps are protected to avoid heat losses.

**Brooders.**—According to the California station, when radiation is depended upon in brooders as the method of heat transfer and the elements are operated at glowing temperature, the hover is generally 3 or 4 feet high, no curtains are used, and little or no trouble is experienced from sweating. The heating cost at 2 cents per kilowatt hour will average from 2.5 to 3 cents per chick per 1,000 hours. For mild climates 2 watts should be allowed per chick and 2.5 to 3 watts for freezing temperatures. Where radiation is used but the elements do not glow, the hover is low, curtained, and ventilated. The operation costs are lower than with the glowing type and the heaters should have a capacity of from 1.5 to 2 watts per chick. Brooders depending upon convection are comparatively free from sweating troubles and cost from 0.75 to 1 cent per chick per 1,000 hours. The open brooder requires more heat than the curtained brooder but is better ventilated. Seven square inches per chick is recommended as the brooder floor area.

The Oregon station found that slatted floors covered with burlap do not affect the ventilation of brooders but do reduce the sweating. There was less trouble from sweating under hovers heated with coal and oil stoves than with electric hovers of the radiant heater type. It was concluded that sweating is not controlled so much by ventilation as it is by the temperature of the floors and of the lower part of the chick's body.

### LAND CLEARING

**Stump removal.**—The California station reported that the cost of clearing land of 6 to 18 inch oak stumps with the barrel-type stove is considerably lower than by use of the pulling process. Green or wet stumps opened with a light powder blast in the winter or spring were found to burn readily the following fall. Dry softwood stumps burned to a depth of from 4 to 8 feet below the ground level, but green or wet stumps did not burn below tillage depth.

**Stone removal.**—In most cases the cost of stone removal is largely a labor cost, according to the Minnesota station. In the disposal of stone by burying, the cheapest excavation was obtained by placing one large charge of explosive in the bottom of a 10-foot hole. An excavation so made will hold about 10 cords of stone and when pyrotol is used the cost of burying is about $1.50 per cord. It appears that a deep hole is the most efficient per unit of surface dirt removed which must be returned.

### MATERIALS

**Draintile.**—The Minnesota station found that bedding with loose sand containing 2.5 and 5 per cent of moisture produced the most favorable conditions of pressure distribution in draintile, while bedding with thoroughly compacted dry sand produced the most severe conditions.

**Fence posts.**—The Missouri station reported that in general the most effective treatments for wood fence posts are the double tank treatments of creosote. Willow was more favorably affected than was cottonwood.

The Arkansas station found that lime-sulphur spray solution has little value as a wood-post preservative. Painted steel posts were found to show considerable rust after four years' service, while galvanized posts were in good condition. Of 148 butt-treated,

open-tank process, creosoted green oak posts, 22 per cent were unfit for service after five years. In the treatment of wood posts with water-soluble toxic salts it was found that slightly more salt was absorbed by cooking the posts for two hours at 180° F. than by soaking them overnight in the cold solution. Steeping in cold solution for as long as 24 hours per inch of thickness did not cause sufficient penetration.

### SANITATION

**Sewage disposal.**—As the result of a 5-year study the Illinois station concluded that in general a 2-chamber septic tank will give the best results.

The New Jersey stations found that treatment with lime stopped foaming in Imhoff tanks and that if the reaction of incoming fresh solids is kept at pH 7.3 to 7.6 odors are practically absent and the time of digestion is decreased. With such reaction control the per capita digestion space can be reduced from 2.6 or 2.7 cubic feet to 1.4 or 1.5 cubic feet. It was further found that the distribution of solid material is more uniform in a deep tank than in a long, shallow tank of the same capacity.

### ECONOMICS AND SOCIOLOGY

**Farm organization.**—Using a study made during 1922–1924 in Kingsbury County, the South Dakota station prepared tables of standard material and labor requirements, yields, and prices for that section of the State, and outlined two suggested systems of farm organization each for 160, 240, and 320 acre farms. It is estimated that the suggested systems would increase operator's labor incomes by from $217 to $347 on the 160-acre farms, $423 to $437 on the 240-acre farms, and $684 to $733 on the 320-acre farms. The North Dakota station, in comparing the data from farms in the southwestern part of the State studied in 1922 and 1925, found that the 480 to 600 acre farm seemed to be the most economic unit and that farms were tending to that size.

From a detailed study of 38 representative dairy farms in Steele County for the years 1920-1924, the Minnesota station determined the standard man labor and horse work requirements for producing different crops, and the standard man labor and horse work and feed requirements for producing different types of livestock, and also the distribution of labor throughout the year, with a view to using these standard requirements as a basis for recommending the reorganization of individual farms. Similarly the North Carolina station worked out equipment, livestock, and cropping systems for farms in the lower coastal plain with 40, 60, and 70 acres cropped.

A study of irrigated farms in northern Colorado during the period 1922–1925 by the Colorado station brought out the facts that four of the five farms with the highest net returns had larger percentages of the crop area in cash crops—beets, potatoes, beans, and wheat—and smaller percentages in alfalfa, barley, and oats than did the average farms. Lambs or cattle, or both, were fed also each year on the four farms. On the five most profitable farms the cost of horse work averaged 12.3 cents per hour and the number of hours work per horse 1,124 per year, and an average of 20.4 acres was handled per horse, as compared with 17 cents per hour, 671 hours per year, and 13.9 acres per horse on the five least profitable farms.

**Cost of production of field crops.**—Increased efficiency of the farmers, lower land rent, lower value of farmers' labor, and lower prices of commodities used by the farmers have resulted, according to a study made by the North Dakota station, in decreasing the cost of producing the principal field crops of that State by about 60 per cent from 1920 to 1925. The Kentucky station, on a route in Christian County, found the average man labor and horse work requirements per acre for different crops from 1921 to 1923 to have been 262.9 and 82.7 hours for tobacco, 23.6 and 37.9 hours for corn, 11 and 22.5 hours for wheat, and 10.2 and 11.1 hours for mixed hay.

The average yield per acre and cost of production of soy beans on 281 farms studied by the Indiana station in 1923 and 1924 were 14 bushels and $1.46, respectively. The cost on 73.9 per cent of the farms was between 75 cents and $2 per bushel. Sixty-two per cent of the farms studied produced soy beans at a profit. The average labor requirements to grow and market the crop were 15.6 hours of man labor, 26.3 hours of horse work, and 1.7 hours of tractor work per acre.

**Cost of producing tobacco.**—The Virginia station found from a study during the period 1922–1925 of dark-tobacco farms and bright-tobacco farms, with averages, respectively, of 46.1 and 34.2 acres cropped and 8.1 and 9 acres in tobacco, that 26.4 months of man labor were required on the dark-tobacco farms and 28.6 months on the bright-

tobacco farms, of which 42 and 65 per cent, respectively, were used on tobacco. The average operator's earnings, less food, fuel, and house furnished by the farms, decreased from $331 to —$129 on the dark-tobacco farms and from $184 to —$451 on the bright-tobacco farms. Increased production of poultry, hogs, cows, and foodstuffs, better management of wood lots, use of larger fields and larger machinery and barns, and the abandonment of certain lands for cropping are factors that will assist in increasing incomes in these sections. The Kentucky station found that during the period 1919–1922 an average of 330.4 hours of man labor and 97.6 hours of horse work were required to raise an acre of Burley tobacco and 252 hours of man labor and 84.3 hours of horse work for an acre of dark fire-cured tobacco. The average cost of production per acre was $238.30 for Burley and $105.44 for dark fire-cured tobacco. The average return to tenants was 46.3 cents per hour of labor on a one-half share rent basis on the Burley tobacco farms and 22.4 cents per hour on the dark fire-cured tobacco farms on a one-third share rent basis.

**Large-scale cotton production in Texas.**—The Texas station found, in a study in the Corpus Christi and San Angelo areas, that one man with a tractor can handle the field operations for raising at least twice the acreage of cotton than can be handled by one man with four horses. The number of horses required to do the same amount of work as a tractor varied from 5.21 in planting with a two-row planter to 13.7 in cultivating with a six-row outfit. Using the data from the Corpus Christi area, it was calculated that with tractor power 718 hours of man labor and 662 hours of tractor work costing approximately $653 would be required to bring 200 acres of cotton up to picking, as compared with 1,694 hours of man labor and 6,478 hours of horse work costing approximately $1,505 on a horse-operated farm.

**Cost of feeding cattle in Iowa.**—From a study of 550 lots of feeding cattle in Pottawattamie County, Iowa, during the period 1918–1923, the Iowa station found the average cost per pound of gain was 16.8 cents. The price of corn was the largest single factor, a change from 80 cents to $1 per bushel increasing the cost nearly 3 cents per pound. A change from 1:15 to 1:14 in the cattle-corn ratio reduced the profits about $2.40 per head. An additional margin of $1 per 100 pounds between the price of steers when fattened and when purchased as feeders increased the profits about $1.25 per head. Within reasonable limits each additional month of feeding increased the cost per pound 0.3 cents. Increasing the number fed from 1 to 2 carloads saved eight hours of labor per month per car, decreased the rate of gain 0.1 pound per day, and increased the cost of gain about 0.6 cent per pound. An increase of 0.5 pound per day of gain over the average decreased the cost per pound of gain about 2.3 cents.

**Cattle-ranch returns.**—An investigation of 60 ranches made by the Wyoming station showed the average return on the investment to be 5.66 per cent, of which more than half resulted from increase in inventories. Taxes equaled 12.7 per cent and interest paid 18.4 per cent of the ranch income. High land values and land taxes made leasing more conducive to profits than owning land. The New Mexico station, from a study of the records for 1925 of 112 cattle ranches, found that the ranches with from 301 to 500 breeding cows were the most profitable, notwithstanding that the investment and total indebtedness per animal unit were $5.56 and $3.03, respectively, higher than the average for all the ranches. The return on such ranches was 18.07 per cent on the total investment and 4.85 per cent on average valuations, as compared with 15.44 and 0.02 per cent for the 112 ranches. In a study for the year ended March 31, 1925, of 71 ranches in the sand-hill section of Nebraska, made by the Nebraska station, it was found that the net income was $1,441, which, allowing $987 for wages for the operator and family, left a return on the operator's equity in the capital invested of only 0.99 per cent.

**Dairy-farm returns.**—Further reports on dairy-farm studies in New York were published by the New York Cornell station. Of the 182 farms studied in 1922 and 1923, 73 failed to make interest and only 39 had labor incomes of over $1,000. The average farm incomes in the two years were $836 and $1,160, respectively, and the labor incomes $32 and $383, respectively. Of 76 farms, for which the 1922 records were the third successive year, only 3 had made labor incomes of over $1,000 each year. The operation of these three farms emphasized the fact that for continuous success in the region studied, it is essential that the farm be not overcapitalized, that it has a good 2-man dairy of about

30 cows, and that enough cash crops are produced to more than pay the hired help.

In further studies in Franklin County, Vt., by the Vermont station it was found that the greatest net earnings were on land valued at from $11 to $20 per acre, and that the highest profits per cow were on farms of from 126 to 150 acres of crop land and open pasture and with 20 to 30 cows. Purebred and grade herds rather than mixed lots and scrubs, purebred sires, winter dairying, and cows producing from 175 to 200 pounds or more of butterfat were important factors in the profitableness of dairying. Cows yielding 200 pounds or more of butterfat on medium grain rations gave the greatest profits. Indications were that the reduction in the cost of producing milk offers better opportunity for increasing profits than does an attempt to secure higher prices.

**Sheep-ranch management.**—The Wyoming station, from a study of 65 of the larger sheep ranches in the Red Desert area in 1925, found that the average return, after allowing 8 per cent on capital and $2,507 for operator's labor, was 5.4 per cent, being $1.10 per ewe. An assessed valuation of 39 cents per acre would permit owners to own winter range, but with the present high assessment of land, averaging $2.84 per acre on the ranches studied, private ownership of ranch land is unprofitable. The ranches with from 4,000 to 9,000 breeding ewes gave the best returns, and it was found that the number of sheep handled by one man should be from 650 to 1,000, and that with less than 550 the chances for favorable returns were small.

**Poultry raising costs and incomes.**—An economic study made by the Washington station of 131 poultry farms showed that the labor costs for the years 1924 and 1925 were 26 and 85 cents per bird higher for flocks of less than 500 birds than for flocks of from 1,001 to 2,000 birds. Individual labor incomes varied from a loss of $1,790 to a profit of $7,487, the averages for the two years being $646.50 and $834.79. A comparison of farm records obtained by the New Jersey stations from 120 commercial poultry plants for the years 1924 and 1925 with those from 150 plants for the years 1915 and 1916 showed the average net farm income and the average labor income had increased $965 and $603, respectively. The acreages in the farms and the cropped areas had also increased from 11.6 and 4.6 acres to 24.5 and 7.5 acres, respectively.

**Returns to shippers and growers of fruits and vegetables.**—An economic survey of the operations of fruit and vegetable shippers in western New York made by the New York Cornell station showed that 69.6 per cent of the returns to shippers from all shipments in 1922–23 was paid to growers, 27.6 per cent went for handling charges, 2.3 per cent for allowances, and 3.1 per cent for management costs, resulting in a loss of 2.6 per cent, which was reduced to 1.6 per cent by the income from by-products. In 1923–24, 92.9 per cent of the returns was paid growers, 27.7, 0.6, and 3.9 per cent, respectively, were absorbed by the other charges, and only 0.9 per cent was received from by-products, resulting in a net loss to the shippers of 24.2 per cent. In 1922–23 the growers received 55.9 per cent of the city sales price of the products shipped on consignment, and in 1923–24, 81 per cent.

**Cattle prices.**—The Iowa station found that cattle prices show a high degree of sensitiveness to variations in business activity, the changes occurring as soon and often sooner than those in the index of prices of 10 sensitive commodities used by the Harvard economic service, but lagging about three months behind the changes in the price index for a series of industrial stocks used. Hog prices appear to move in sympathy with cattle prices, but because of the differences in demand many of the most significant changes in cattle prices precede by one or two months the changes in hog prices.

**Marketing of hogs.**—An investigation made by the Illinois station showed that 72.1 per cent of the variations in the receipts of hogs at Chicago could be accounted for by the corn-hog ratios at the time of breeding (December), for six months preceding breeding, and for three months after breeding, the several ratios being "lagged" at varying periods. Climatic conditions at farrowing time were found to account for 18 per cent of the variations in receipts. The December hog-steer ratio, changes from previous years of the percentage of nonmerchantable corn, disease losses, and the estimated number of breeding sows on farms were found to be of only minor importance in affecting the receipts.

The changes in a pork-product index computed using the prices of pork loins, breakfast bacon, smoked hams, and pure lard, weighted in the proportions of 1, 1, 2, and 1, were found

by the Iowa station to agree quite closely with the fluctuations in hog prices during the period 1920–1925. Two distinct trends were found in the prices of hogs from 1869 to 1914, a downward movement from 1869 to 1896, averaging 3.45 cents per 100 pounds per year, and an upward movement from 1897 to 1914, averaging 25.7 cents per 100 pounds per year.

**Cooperative marketing of livestock.**—The Wisconsin station, in an investigation of cooperative livestock sales organizations, found that approximately 15 per cent of the receipts at the St. Paul, Milwaukee, and Chicago markets is handled by such associations. About half of the livestock shipping associations of Wisconsin are members of such organizations and handle about 73 per cent of the livestock shipped through their organizations. Besides keeping farmers better informed as to market conditions, improving market services, and bringing about more orderly movements to market, the cooperative livestock sales organizations were able to refund approximately 25 per cent of the paid-in commissions, thus reducing the marketing cost by about 0.5 per cent of the total sales value of the stock. The Kentucky station, from a study of livestock auction sales organizations, found the costs per head of sales made by such organizations varied from 18.2 to 34.3 cents, averaging 22.7 cents. The average profits ranged from 2.4 to 13.3 cents per head, averaging 6.7 cents.

**Cooperative egg and poultry assembling.**—A study made by the Minnesota station brought out the fact that, through the efforts and control of the cooperative egg and poultry assembling units and their cooperative overhead association, the percentage of eggs handled by the association that graded as extras and standards increased 3.6 and 1.4 per cent, respectively, from 1925 to 1926. The eggs collected and handled by the cooperative assembling units from April 15 to August 31, 1926, also brought from 1.9 to 4.4 cents more per dozen than those handled by creameries which also sold through the association.

**Milk marketing.**—Independence of milk markets was found to be disappearing by the Pennsylvania station because of the overlapping of territories tributary to the several markets, the consolidation of distributing companies, and the improvement of transportation facilities. Uniformity of marketing plans and price policies in different markets are needed to obtain equitable payments from distributors, to effect an equitable distribution of proceeds to producers, and to encourage economic production and marketing of milk throughout adjoining regions.

**Taxation.**—A study made by the Missouri station showed that the average tax per acre of farm lands rose from 8 cents in 1881 to 15 cents in 1913, to 23 cents in 1919, and to 40 cents in 1924. On the farms studied, real estate taxes in 1923 absorbed an average of 20 per cent of the net rents and when measured in percentage of rents were 100 per cent higher than in 1919. The ratio of assessed valuations to owner's estimated valuations on the farms studied increased from 14.6 per cent in 1919 to 105.1 per cent in 1923, as compared with an increase of from 54.6 to 64.4 per cent for city real estate. The average percentage, 1919–1923, of capitalized net rent of the owner's estimated value was found to be 38.5 per cent less for rural than for urban real estate, and the ratio in 1924 of assessed value to selling price was 7.3 per cent more for rural than for urban real estate. Farm taxes in 1924 in Boone County were distributed 9.9 per cent for State purposes, 45 for county purposes, and 45.1 per cent for special district purposes. To correct the inequalities in taxation, it is suggested that property taxes be made to reflect more fully the variations in the earning capacity of different classes of property, that a larger proportion of taxes be obtained from other sources than property, and that the State assume a larger percentage of the cost of administration, schools, roads, etc.

Taxes on farm real estate were found by the North Dakota station to have increased from 23 cents per acre in 1926 to 48 cents in 1924. Of the general taxes of the State, 13.36 per cent were for State purposes, 22.16 for county purposes, 8.49 for city, town, and village purposes, 8.18 for township purposes, and 47.81 per cent for school purposes. Lack of stability of the value of farm products, variations in the cost per child and assessed valuations per child in maintaining schools up to State requirements, lack of uniformity in making assessments, and variations in the benefits received from roads were the chief causes of inequality in the farm taxes of the State.

A series of index numbers for farm taxes was computed by the New York Cornell station for 34 townships in 34 counties of the State, using the average for 1910–1914 as equal to 100. The index numbers rose from 55 in 1887 to 62 in 1903, to 123 in 1916, and to 220 in 1924. It was also found that while

in 1887 29.8 per cent of the general property taxes went for county purposes, 24.4 per cent for township purposes, 21.8 for school purposes, and 24 per cent for State purposes, in 1924, 22, 44.1, 27.5, and 5.4 per cent, respectively, went for these several purposes. The Wisconsin station, in a study in Dane County, found that while from 1913 to 1924 farm and city incomes increased 15 and 118 per cent, respectively, the taxes increased 138 and 326 per cent, respectively. The percentage of farm incomes absorbed by taxes increased from 12.3 per cent in 1913 to 22.5 per cent, and that of city incomes from 4.8 to 8.9 per cent.

The fact that while farm real estate is assessed at a lower percentage of its value than urban and industrial real estate, a larger share of the farmers' income is taken by taxes than that of certain other industrial and professional classes was brought out in an investigation made by the Massachusetts station. The ratios of assessed value of farm real estate to owner's values varied from 30 to 100 per cent in the same town, and the average ratios as much as 20 per cent between towns. The ratios of assessed to reported value of livestock also varied as much as 60 per cent between neighboring farms, and there was but little uniformity even between adjacent towns. The appraised valuations for taxation purposes of 379 farms sold in five counties in Ohio during the year ended July 1, 1926, were found by the Ohio station to have varied from 70.1 to 88.2 per cent, averaging 81.3 per cent of their sale prices.

**Farm credit.**—The Texas station, in a study of short-time farm credit, found that about 69 per cent of the farmers reporting obtained credit during 1925, the average amount being $751. Approximately 40 per cent of the money borrowed from banks was used for consumptive purposes and 60 per cent for productive purposes. The average loss on bank loans to farmers from January 1, 1921, to July 1, 1925, was 0.6 per cent. Approximately 28 per cent of the 1924 accounts owed to merchants reporting were carried over to 1925, and about 3.1 were finally lost.

**Farmers' attitude toward farming.**—The South Dakota station, in a study of 150 farm families in Lake County, found that 87 per cent of the farmers and their families were satisfied with the farm as a home and mode of living. Of the children, 79.9 per cent of those over 21 years of age were farming, and 89.2 per cent of the younger boys expressed a desire to farm. Seventy-eight per cent of the farmers stated that they would farm if starting again, 93 per cent wished their sons to farm, and 62 per cent were making a specified effort to keep their children on the farm.

**Attitude of farmers toward rural organization.**—The Virginia station found that rural organization in Virginia is more extensive than is generally realized, but that a comparatively small percentage of the people are especially interested or taking an active part in it. Publicly supported institutions are giving increasing attention to the subject, but other public opinion-forming agencies appear to be less concerned. The movement has been hampered by disinclination to change existing methods and practices, failure to fully realize the importance of problems needing group effort, and lack of widespread knowledge of what can be done by organization to promote rural betterment.

**Attitude of farmers toward cooperation.**—The Minnesota station, from a study in nine communities representative of the principal agricultural areas of the State, found that more than 60 per cent of the farmers interviewed were favorable to cooperative buying and selling, use of membership contracts and the withdrawal clause in such contracts, pooling, central control of grading, selling, and quality of production, and advertising by central organizations. The structure of previous experience and thinking, actual experience, business conditions, geographic distance, social distance, extreme wealth or poverty, and old age were found to be important factors affecting attitudes and behavior variations. Farmers in general were found not to be individualists but to behave according to the same social principles as other people, the only important differentiating influence being occupational environment.

**Costs and standards of living.**—A study made by the Iowa station in Boone, Story, and Sac Counties showed that the average cost of living for the year ended July 1, 1923, was $1,875.90 for owner families and $1,506.40 for tenant families, of which amounts 40.3 and 42.8 per cent, respectively, were the values of home-produced commodities. The costs for 6.6 per cent of the owner and 9.2 per cent of the tenant families were $1,000 or less. Six and six-tenths per cent of the owner and 1.2 per cent of the tenant families had costs over $3,000. Size of farms,

value of land, and value of house seemed to have no definite relationship to the average cost consumption unit or the percentage of the total expenditures used for advancement. Expenditures for advancement increased slightly with the number of children up to five and were greater where the operators and their wives were over 41 and 45 years of age, respectively. The extent of the education of the children was found to be the best indication of the standard of living of the family.

**Cost of feeding the farm family.**—The average money value for the year ended May 30, 1924, of the food consumed per household in 342 farm homes studied by the Nebraska station was $735, of which about two-thirds consisted of the money value of food produced on the farm. While the amount actually spent by farmers for food was only approximately half as great as that spent by wage earners' families in Omaha, the value of the home-raised foods brought the value up to nearly twice as much.

## RECENT FERTILIZER EXPERIMENTS WITH COTTON

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Fertilizers have long been recognized as an especially important factor in cotton production in the Southern States, and particularly since the Civil War (1861–1865). Before that period land and labor were both cheap and abundant, and cotton land was exploited and abandoned when no longer productive. The changed conditions following the war compelled the recultivation of lands once cast aside as unprofitable. In this postwar period, when chemical fertilizers were first assuming commercial importance, the real beginning of the use of fertilizers on cotton was taking place. After a time the cotton growers have begun to realize that for profitable returns fertilizers must be supplemented by crop rotations, improved cultural methods and better varieties, and other practices.

The present importance of fertilizers in the cotton industry may be measured by the quantities of fertilizer used on the crop in the cotton States. Of 48,890,000 acres reported in cotton in 1926 (*46, p. 965*),[4] 18,256,000, or more than 37.3 per cent, received fertilizer. While fertilizers are used for cotton in all the cotton States east of the Mississippi, the heaviest use is on the coastal plain in North Carolina, South Carolina, Georgia, and Alabama, and in the Piedmont regions of these States. In recent years the use of fertilizers has extended into the cotton States west of the Mississippi.

Investigations by the experiment stations in the Southern States have played a highly important part in furthering the use of fertilizers on the cotton crop. The earlier experiments were of necessity of such simple types as trials of sources of materials, comparisons of formulas, and tests of time, rates, and methods of application. In later years, however, a greater proportion of the experimental work has been directed toward the more fundamental aspects of the problem and has dealt with the chemical composition and nutrition of the cotton plant, its response to the different forms of the several nutrient elements, and the different plant-food requirements of the crop on the several soil types. Much of the earlier work on this problem has been reviewed in another publication of this office (*47*) and in the recent books of Brown (*48*) and of Collings (*49*).

The present paper aims to present a cross section of the investigations of the experiment stations with fertilizers for cotton reported during the years following the end of the World War (1919–1927). Fertilizer mixtures, arranged from the results of experiments, are given, together with accounts of the relative merits of different sources of the nutrient elements, methods of application, and related practices. The paper has been necessarily limited to results and recommendations, although technic is discussed briefly in conclusion.

### GENERAL FERTILIZER PRACTICE

Fertilizer practices for cotton on the distinct soil divisions of Alabama have been recommended from the results obtained in 226 local cooperative fertilizer tests carried on by the Alabama station (*2*). The least returns from commercial fertilizers were had on the black-belt soils. Sodium nitrate was responsible for better profits than cottonseed meal in all sections of the State and is recommended in each of the formulas given. Early applications were found to pay better than late applications. The returns from all fertilizers, except sodium nitrate, were lower after the advent of the boll weevil.

The gray soils over yellow subsoils of southeastern Alabama were found to need considerable potassium and relatively little phosphorus. Somewhat less potassium seemed to be required by all red soils, the gray soils with red subsoils, and, in the southwest part of the lower coastal plain, by the gray soils with yellow subsoils, and the response to phosphorus on

[4] Numbers in italics in parentheses refer to "Literature cited," p. 85.

these soils was relatively low. The fertilizer needs of the upper coastal plain resembled those of the soils of southwestern Alabama, on which sodium nitrate produced especially good results.

Soils of the Piedmont and Appalachian Plateaus responded well to sodium nitrate and superphosphate (acid phosphate), although their needs for potassium were comparatively low. The gray or yellow chert-free soils with heavy yellow subsoils of the limestone-valley regions appeared to need much potassium and to give a good response to superphosphate and sodium nitrate. Sodium nitrate produced greater returns on the red lands of the limestone valleys than on any other soils of Alabama and a strong need for phosphorus and a low potassium requirement were indicated. Superphosphate was used to its best advantage on the highland rim, and a moderate amount of potassium returned good profits in this area.

The average results of numerous experiments by the Alabama station (*4*) demonstrated that a complete fertilizer gives best results on cotton on nearly all Alabama soils. Its recent tests on the rate and ratio of applying fertilizer to cotton conducted on Norfolk, Orangeburg, Dekalb, and Decatur soils indicated that the proper rates for combining materials for cotton is sodium nitrate 100 pounds, superphosphate (acid phosphate) 200 pounds, and potassium chloride 25 pounds.

Cooperative fertilizer experiments with cotton by the Arkansas station (*5*) showed that, while nitrogen is the limiting element with the crop in the State as a whole, the best returns are rarely to be had from nitrogen unless it be used with phosphorus and potassium. Basic fertilizer recommendations have been made for cotton on the interior coastal plain soils, on the hill soils, and on the lowland soils of medium to low fertility. The station indicated that on the heavy soils of the lowland section from 100 to 150 pounds of sodium nitrate alone could be used. The favorable results which followed the use of manure called for its better preservation.

Fertilizer tests by the Georgia station (*10; 11, p. 71–72*), cooperating with the United States Department of Agriculture, showed that nitrogen and phosphorus were of importance in growing cotton on Piedmont soils and that the need for potassium was secondary. The Georgia Coastal Plain station (*14*) has indicated a 9–3–5 (P–N–K) fertilizer formula for cotton on typical Tifton sandy loam, recommending a slight increase in the nitrogen and potassium on lighter soils. On good soils from 800 to 1,000 pounds per acre seemed desirable, and quickly available nitrogen sources were preferred. Liming was not economical, whereas green manure in combination with complete fertilizer gave good results with cotton.

The Holly Springs, Miss., substation (*22*) advised for cotton from 400 to 600 pounds per acre of a complete fertilizer or of a mixture of superphosphate 200 pounds, sodium nitrate 100 pounds, and potassium sulphate or potassium chloride 25 pounds, or kainit 100 pounds. Experiments at the Raymond, Miss., substation (*23*) indicated from 500 to 600 pounds per acre of a complete fertilizer, with modifications for certain conditions. Experiments at the South Mississippi substation (*24*) demonstrated the importance of nitrogen and phosphorus for cotton, whereas marked reduction did not follow the omission of potassium. Potassium in the form of kainit appeared to have enabled the plants to retain their foliage throughout the season. Enhanced yields of seed cotton accrued from the use of lime. Considering experimental results and experience, the Mississippi Delta substation (*20*) concluded that nitrogenous fertilizers used alone seemed most economical for the Delta, except along the foothills and on soil on which cotton either wilts or rusts badly. On such soils potassium usually pays, and both potassium and phosphorus are needed on some of the eastern border of the Delta. This substation (*25*) also advised that superphosphate should be used on Delta soils derived from the hills.

Experiments in southeastern Missouri (*28*) indicated that in general sodium nitrate should not be used alone, whereas superphosphate alone may be profitable with cotton on most soils in the region. A high-grade complete fertilizer or a combination of superphosphate and potassium chloride is indicated as generally giving good returns over a wide range of soil types and conditions.

Fertilizer tests by the New Mexico station (*29, p. 45*) indicated that on the heavier types of soil not too heavily cropped to cotton commercial fertilizer was unprofitable, especially when barnyard manure had been applied or the cotton followed alfalfa. On lighter soils 300 pounds of superphosphate per acre was more profitable than a complete fertilizer.

In fertilizer experiments made by the North Carolina station (*30*) on Cecil sandy loam soil in the Piedmont and on Norfolk fine sandy loam in the costal plain, as measured by the average percentage of cotton open at first picking, increases in the phosphorus in the formula made for earliness, in the nitrogen caused little or no change, and in the potassium made the cotton later on both soils. Application of commercial fertilizer usually increased the percentage of cotton open at the first picking as compared with unfertilized cotton. Increasing the quantity of fertilizer per acre had a rather marked effect on maturity. From 600 to 800 pounds of complete fertilizer per acre was recommended for the more important soils of the Piedmont and of the coastal plain. The percentage of nitrogen at planting should be reduced to about half if as much as 100 to 150 pounds of sodium nitrate or ammonium sulphate is used as a side dressing after chopping.

Applications of fertilizer carrying large quantities of nitrogen or phosphoric acid seemed to have a residual effect lasting for several years in tests on Cecil sandy loam by the South Carolina station (*33*). Phosphorus, closely followed by nitrogen, appeared to be the prime limiting factor on the soil, whereas potassium was considered of doubtful value. Lime reduced yields slightly when used with superphosphate alone and caused a slight increase when used with a complete fertilizer, but its application on this soil solely for cotton production did not seem profitable. Superphosphate with blood gave better results than any other combination of two elements. Manure (8 tons) with superphosphate (300 pounds) produced the highest yields of the several treatments used. It was found very difficult to maintain cotton yields on this soil by the use of commercial fertilizer alone.

Fertilizer tests on seven of the leading soil types in South Carolina (*34*) showed that a properly balanced fertilizer produced the earliest crop and the highest yield, with applications of from 600 to 800 pounds per acre giving the most profitable returns. Nitrogen was the prime limiting factor in cotton production and phosphorus the next, both of which seemed to influence the earliness of the crop. Small amounts of potassium increased yield, while heavy applications tended to delay maturity and reduce the yield. From the results of all of its fertilizer experiments with cotton the South Carolina station (*38, p. 19–20*) recommended for the coastal plain 600 to 800 pounds per acre of fertilizer containing 9 to 12 per cent of phosphoric acid, 3 to 5 per cent of ammonia, and 3 to 4 per cent of potash, with 150 pounds of sodium nitrate or 110 pounds of ammonium sulphate as a side application, and for the Piedmont from 600 to 800 pounds containing from 10 to 12 per cent of phosphoric acid, 3 to 5 per cent of ammonia, and 2 to 3 per cent of potash, with the same top-dressing as for the coastal-plain soils.

Fruiting studies made at the South Carolina Pee Dee substation (*39*) showed that cotton on plats receiving nitrogen and potassium without phosphorus fruited slowly during the first part of the season and reached the peak late. Phosphorus and potassium without nitrogen resulted in early season fruiting. While the fourth week was the most productive, there were only two weeks of rapid fruiting. Although phosphorus and nitrogen used alone stimulated early season fruiting, the period of rapid fruiting appeared to be comparatively restricted through the omission of potassium.

Results of fertilizer experiments by the Tennessee station (*40*) suggested the use of 200 pounds of superphosphate per acre for cotton, even on soils that were fairly well supplied with phosphorus, with a heavier application for the highland rim and eastern Tennessee soils. From 100 to 150 pounds of sodium nitrate or its equivalent in cottonseed meal should be applied where needed. A high-grade fertilizer mixture seemed excellent for cotton and preferable to low-grade mixtures. Although the differences were not large, liming was apparently profitable for cotton and for other crops grown in rotation with cotton.

Superphosphate produced a gain in 75 per cent of the cotton tests, cottonseed meal in 68 per cent, and potassium in 53 per cent in extensive fertilizer experiments by the Texas station (*41*). Superphosphate appeared to be the most certain and most profitable fertilizer for cotton, while a mixture of equal parts superphosphate and cottonseed meal at the rate of from 150 to 200 pounds per acre appeared to be the best mixed fertilizer for general use. The inclusion of potassium in mixed fertilizers appeared inadvisable, except where the soil is known to be deficient in potassium, in which case from 150 to 200 pounds of complete fertilizer is advised. Good immediate and residual effects were also obtained from

barnyard manure. From a study of the chemical composition of the cotton plant this station (*42*) estimated that the probable needs of cotton per 300 pounds of seed cotton or 100 pounds of lint are 7 pounds of phosphoric acid, 25 pounds of nitrogen, and 15 pounds of potash. The draft on the soil was not in direct proportion to the size of the crop, being somewhat larger for small crops and somewhat less for large crops.

Fertilizer tests with cotton in Nansemond County by the Virginia station (*45*) indicated for general use from 300 to 600 pounds per acre of a complete fertilizer, with the nitrogen reduced on soils adequately supplied with this element. Lime was not beneficial except when used with nitrogen and potassium, and even then the increase was hardly profitable.

### NITROGEN SOURCES

Considering the effect on cotton production by nitrogen in the form of sodium nitrate as 100, the Georgia station (*9, p. 7–8*) found that nitrogen in a mixture of sodium nitrate and cottonseed meal produced 114.7, ammonium sulphate 101, velvet-bean meal 100, cottonseed meal 100, sodium nitrate and ammonium sulphate 93.7, dried blood 86.8, and peanut meal 75.9. In later trials at this station (*11, p. 71–72*) sodium nitrate and ammonium sulphate produced about as much cotton as organic forms of nitrogen, and the differences in costs made the salts preferable. A combination of nitrogen from organic and inorganic sources appeared to give better cotton yields at the Georgia Coastal Plain station (*13*) than nitrogen derived from a single source.

The average results during four years at the Mississippi station (*27*) showed sodium nitrate and ammonium sulphate to be about equal as nitrogen sources for cotton, calcium cyanamide somewhat inferior, and cottonseed meal even less valuable. The Mississippi Delta substation (*17, 18, 25*) has found ammonium sulphate, and also sodium nitrate and cottonseed meal, alone or in combination, to surpass other commonly used nitrogen sources for cotton. Ammonium sulphate and sodium nitrate were similar in effectiveness per pound of nitrogen. Cottonseed meal, if as cheap per pound of nitrogen, seemed as economical as other nitrogen sources.

Sodium nitrate was found by the North Carolina station (*31*) to be the most efficient nitrogen carrier for cotton, surpassing ammonium sulphate, dried blood, calcium cyanamide, and tankage in the order named. In comparison (*30*) with sodium nitrate, dried blood and cottonseed meal were each relatively less effective on Norfolk sandy loam in the coastal plain than on Cecil sandy and clay loam in the Piedmont, and they averaged only about four-fifths as effective as sodium nitrate or ammonium sulphate. Sodium nitrate in two equal applications gave better yield increases with cotton on Piedmont soils than dried blood applied all at planting or half at planting and half after chopping. On the coastal plain soil the best results were had with half the nitrogen as dried blood with the phosphorus and potassium at the time of planting and the other half as sodium nitrate.

The South Carolina station (*36*), cooperating with the United States Department of Agriculture, found air-derived nitrogen salts to compare favorably with sodium nitrate and ammonium sulphate for cotton. Cyanamide in mixture with superphosphate and potassium reduced the yields when enough was applied to serve as the sole nitrogen source, whereas good results were had when it supplied only part of the nitrogen. Combinations with the nitrogen derived from more than one source generally gave better results than when the nitrogen came from either sodium nitrate or ammonium sulphate alone. Sodium nitrate produced slightly more cotton than ammonium sulphate in mixed fertilizers.

### RATES AND TIME OF APPLYING SODIUM NITRATE

Sodium nitrate made its best returns at the Georgia station (*11, p. 71–72*) when it was applied at the rate of 166 pounds per acre. Seed cotton yields rose at this station (*12, p. 127*) with the increase in the quantity of sodium nitrate applied. Tests at the Tennessee station (*40*) suggested from 100 to 150 pounds of sodium nitrate, while the Georgia Coastal Plain station (*14*) recommended from 100 to 125 pounds of sodium nitrate or its equivalent in ammonium sulphate applied at chopping.

Cotton receiving a complete fertilizer before planting at the Alabama station (*1*) made its best average yield increases when the sodium nitrate (140 pounds) was applied at the first cultivation after chopping, i. e., 40 days after planting. In local experiments sodium nitrate (100 pounds) gave its best returns when it was applied at or before the formation of the first

squares. The use of an additional 100 pounds about three weeks after the beginning of blooming was more effective and slightly more profitable than the single 100 pounds at about the time of the appearance of the first squares. The nitrate of sodium nitrate applied at the rate of 600 pounds per acre for cotton 14, 40, and 61 days after planting was absorbed in 36, 14, and 11 days, respectively, at the Alabama station (*3*), there being a close correlation between the rates of growth and of nitrate absorption. The results suggested that the loss of soluble nitrogenous fertilizer might be reduced by delaying the application until the crop is able to absorb it rapidly.

The Georgia station (*11, p. 71–72*) observed that nitrogen applied at the time of planting appeared to give the best results, and it (*12, p. 127*) found that top-dressings of sodium nitrate at planting or chopping were about equally effective, while application at squaring was followed by an acre loss of 150 pounds of seed cotton. Fifty pounds of sodium nitrate applied at planting and 50 pounds at the first squares showed greater profits than any other time of applications at the Mississippi Delta substation (*17, 18*). The results indicated that application of sodium nitrate should start soon after chopping and be completed by the beginning of square formation. On deep sandy soil at the South Carolina Pee Dee substation (*35*) sodium nitrate gave best results when applied as a side application soon after chopping, whereas yields did not vary much with different times of application on soil with clay subsoil. The greatest yield increase occurred in certain South Carolina tests (*38, p. 19–20*), where 50 pounds of sodium nitrate was applied at chopping and 50 pounds at first squares, while 100 pounds at the first squares was also effective. In other trials (*34*) yield increases were obtained with each addition to the sodium nitrate application up to the maximum 300 pounds.

#### PHOSPHORUS

Different forms of phosphorus carriers were not found profitable on cotton on valley land at the Mississippi station (*26*). Raw rock phosphate and flowers of sulphur gave a considerable gain when used in combination, in spite of the fact that they seemed to have a depressing effect when used separately. The South Mississippi substation (*16*) found superphosphate to be better than basic slag, raw phosphate, and soft phosphate rock as phosphorus sources for cotton. In the absence of the boll weevil, superphosphate gave earlier cotton than ground rock phosphate or Thomas phosphate at the South Carolina Pee Dee substation (*32*), although total yields were similar. Tests in Texas (*41*) with cotton showed the phosphoric acid of rock phosphate to be about 22 per cent as effective as that in superphosphate. The Georgia station (*6, 7, 8, 9, 10*) has also conducted extensive tests with different sources of phosphorus for cotton.

#### POTASSIUM

The Mississippi station (*19*) observed that potassium in the form of sulphate or chloride seemed as efficient for cotton as the potassium in kainit. Experiments by the South Carolina Pee Dee substation (*32*) showed that 2 per cent of potash was enough for maximum cotton yields in a rotation and 4 per cent for continuous cotton. Potassium chloride and kainit were equally valuable as sources of potassium. Heavy applications of potassium appeared to delay maturity.

#### MANURE

Manure gave profitable gains with or without raw rock phosphate at the Mississippi station (*26*). Manure supplemented with commercial fertilizers gave 15 per cent more cotton yields at the Louisiana station (*15*) than manure used alone.

#### LIME

Beneficial effects from the addition of limestone to cotton land were observed at the Georgia station (*10*). On the other hand, the use of hydrated lime resulted in an average decrease of about 6 per cent in the yield of cotton in 20 tests reported by the Texas station (*41*). At the South Carolina Pee Dee substation (*32*) caustic lime and ground limestone were found of equal value as lime sources when used at rates of 1,000 and 2,000 pounds per acre, respectively, although lime was not profitable on the soil. Lime in a rotation of cotton, corn, oats, and a legume did not show a consistent gain at the Mississippi station (*26*) for any form or quantity of lime used.

#### CROP ROTATIONS

Crop rotations have an important bearing on the economical use of fer-

tilizers. Decided increases were made by cotton following soy beans in tests by the Mississippi Delta substation (*20*). Seed cotton yields at the South Mississippi substation (*21*) after legumes or corn with legumes were in excess of those after corn alone. For cotton production a rotation of cotton, corn, oats, and peas at the South Carolina Pee Dee substation (*37, p. 32–34*) seemed to maintain the fertility as well as 1,000 pounds of a complete fertilizer applied to land continuously in cotton. However, a combination of systematic rotation and adequate fertilization appeared to be needed to produce cotton economically. Cooperative fertilizer tests on representative soil types in South Carolina indicated that applications of phosphorus and potash to corn and oats may be considerably reduced, if not entirely eliminated, when the crops are planted in a regular rotation after cotton liberally fertilized with complete fertilizer. Rotations have been responsible for enhanced cotton yields in northwestern Texas (*44, p. 35*), and in the black-land region of Texas (*43*) cotton yields in rotations were practically double those from continuous cotton.

### SUMMARY OF RECENT EXPERIMENTS

Appropriate applications of fertilizers for cotton are required in order to provide economically for the current needs of the crop and to compensate for the nutrients removed from the land in the seed and lint and lost through leaching, reversion, and denitrification. From the experiments and recommendations cited above, it appears that nitrogen and phosphorus are in greatest demand in cotton production. Potassium appears to be decidedly secondary in importance, except under certain conditions, although its functions are recognized and its omission from the formulas is not generally advised.

Nitrogen in such readily available forms as sodium nitrate seems to be most desirable, although organic sources, including cottonseed meal and other vegetable meals, dried blood, and tankage, have the longer residual effect. Most of the recommendations have been based on sodium nitrate, yet ammonium sulphate and combinations with the nitrogen from two or more sources have also given good results. Some of the newer sources of nitrogen, e. g., ammonium nitrate, ammonium phosphate, and ammonium chloride, have compared favorably with sodium nitrate and ammonium sulphate for cotton. From 100 to 300 pounds of sodium nitrate per acre has been recommended, but the greater margins of profits seemed to be had with the lower rates. Experimental results in general suggest applying half of the sodium nitrate at planting and half at the first squares or else making the whole application at some time between chopping and the appearance of the first squares.

Superphosphate has been preferred to other phosphorus carriers, and while the optimum application rates have varied with conditions, about 200 to 300 pounds per acre seems to be a practical quantity. Potassium chloride, potassium sulphate, and kainit were found similar as sources of potassium for cotton. The need for potassium also varies with local conditions. Manure has given good results, although the supply is quite limited and the nutrients contained in the manure alone may not be in proportions desirable for cotton on the particular soil. Lime in general has seemed of slight value for cotton. The crop rotation has proved to be an important factor in the economical use of fertilizers for cotton.

### CONCLUSION

Examples cited in this review show that the experiment stations have made progress in determining the proper use of fertilizers on cotton. However, much must still be done to obtain uniformity of methods and to correctly interpret the data obtained. The correct interpretation of the results of field trials with fertilizers is a difficult task, because of the many variables involved, besides the differences in crop response to the several fertilizer treatments, such as differences in soil type, soil heterogeneity (in depth, physical structure, and fertility), topography, season, the variety used, the availability of the fertilizer materials, methods of application, care in cultivation, and the methods of recording data. Experiments are frequently rendered valueless by excessive rainfall or drought, poor stands, or damage from insects or diseases. Some of the adverse factors may be minimized by judicious selection of the plat, with knowledge of its cropping history and requirements of the soil type, choice of a representative variety which is stable and uniform, rigid control of cultural operations, adequate replication permitting statistical treatment of the yield data, and repetition

of the experiment during a period of average years.

The general type of the plat test may affect the reliability of the data. Permanent plats at an experiment station permit rigid control of treatment, cultural operation, and in recording data. They are useful in testing the interrelations of the fertilizers and the particular soil and in comparing fertilizer sources, although the cumulative effect of continuous treatment of a plat may lead to erroneous conclusions, and prolonged fertilizer tests may render the soil unreliable for many subsequent comparative tests. This effect can be avoided by placing the series on different blocks in different years. Cooperative tests give information on the fertilizer needs on different soil types, residual effects are minimized, replication is easy, and the results, if not representative, can be discarded without great loss. On the other hand, control over cultural operations and accuracy in securing data are difficult. The experimenter can know little of the nature of the soil and variation within the plat. The separate tests are local in application, although the consolidated results may be indicative for a region. Cooperative fertilizer trials appear to be of particular value in testing under practical conditions the results obtained in pots or soil bins at the central station.

Concurrent with the general trend toward the more fundamental phases of research in fertilizer studies with cotton may be observed a refinement of experimental technic, endeavors to use a standard or uniform terminology, greater care in interpreting results, and more caution in making recommendations.

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# PROGRESS IN THE STUDY OF SOIL HYDROMECHANICS

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The regulation of soil moisture to meet the requirements of growing crops is a matter of concern to both agronomists and agricultural engineers, owing to the cost of the measures employed. Considerable work on various features of the subject has been done at the stations and elsewhere. The results, while more or less fragmentary and disconnected in nature, have served to emphasize the highly complex character of soil and to indicate that water exists and functions in it under many conditions and influences which it does not encounter in the open atmosphere and which may have considerable bearing on its availability to crops.

## SOIL MOISTURE DISTRIBUTION AND AVAILABILITY

Water, when added to soil naturally or artificially, appears to become immediately subject to the numerous influences existing therein. Widtsoe and McLaughlin (1)[5] found that the maximum amount of water held by a deep soil of uniform physical and chemical composition against gravity under field conditions was about 24 per cent on the dry basis and the minimum amount about 8 per cent. The percentage of soil water soon after irrigation was invariably greatest in the top foot and became smaller with increasing soil depth. Under given conditions of soil, crop, water, and time after irrigation the distribution of the soil water was always the same, implying the operation of a definite law governing the distribution of the soil water. Water added to the soil above the amount at which capillary movements became sluggish was distributed through the soil inversely with the distance from the wettest zone, the law of distribution taking the form of the formula of the equilateral hyperbola. Plants could use the soil water below the point at which capillary movements became sluggish, but not readily, and could not use any of the true hygroscopic water. In such soils under field conditions the critical moisture points were the maximum capillary content at about 24 per cent, the optimum content at about 18 per cent, the point at which capillary movements became sluggish at about 12.75 per cent, and the hygroscopic capacity at about 6 per cent.

Patten and Gallagher (2) showed that at the optimum moisture content for crop growth a rapid decrease in the rate of evaporation takes place, accompanied by changes in other physical characteristics of the soil, such as specific volume, resistance to penetration, and the like. This was considered to point to a purely physical reason for the existence of a narrow range of water content in soil at which plants thrive best. It was also found that the content of water in soil at which plants begin to wilt is greater than the quantity which the soil can take up from a saturated atmosphere. In addition a heavy soil containing a high percentage of moisture may hold it so that while the plant can get some water it is by no means fully supplied.

Brown (3) found that the percentage of soil moisture at the time of wilting of several different plants varied with the rate of evaporation at the time of wilting. The residual soil moisture content at the time of wilting varied according to the atmospheric conditions and appeared to be increased by excessive soil temperatures.

Pulling and Livingston (4) also demonstrated the great importance of the influence of temperature on the water supplying power of soil.

Juritz (5) showed that the factor which mainly controls the moisture content of soils is the relative size of the soil particles. Soil texture was considered to be an index of the behavior of soil in relation to moisture in the field. This was taken to indicate that there is a texture of soil which may be regarded as the optimum for certain plants exactly as there is an optimum proportion of moisture in soil for such plants.

[5] Numbers in italics in parentheses refer to "Literature cited," p. 94.

Alway (*6*) found that in general the hygroscopic coefficient is satisfactory as a basis for determining the available moisture in soils, although for matters relating to germination and root growth the wilting coefficient was considered preferable. Nannes (*7*) concluded that the hygroscopicity per cent of sandy, sandy loam, and peat soils should not be less than half the organic matter content, while that of clay soils should not go appreciably below the organic matter content.

These general findings imply that both internal and external physical factors and phenomena strongly influence the manner of existence, movements, and functions of moisture in soils.

### MANNER OF EXISTENCE OF MOISTURE IN SOILS

It seems evident from the above results that total water content presents an inadequate basis for a discussion of soil moisture regulation. Bouyoucos (*8*) pointed out that several different forms of moisture may exist normally in soils with reference to its availability to crops.

**Unfree water.**—McCool and Weidemann (*9*) showed that soils are capable of holding appreciable amounts of water in both physically adsorbed and chemically combined conditions, such that it does not function as a solvent and is inactive from the standpoint of plant requirements.

Bouyoucos (*8*) and Wintermyer (*10*) distinguished between physically adsorbed unfree water and chemically combined unfree water in soils by showing that the former freezes at from —4° to —78° C., while the latter does not freeze at all even at temperatures below —78° C.

Bouyoucos (*11*) showed further that the amount of unfree water in soils does not vary with the different moisture contents, but appears to remain constant so long as the soil remains the same otherwise. This was strengthened by the work of Thomas (*12*) which showed that when comparable vapor pressure-moisture curves of a series of soils, ranging from fine sands to tight clays and from highly calcareous to highly siliceous materials, were considered, all the soils could be divided into two groups, in each of which the relative amounts of hygroscopic water remained nearly constant over a range of from 10 to 95 per cent of the vapor pressure of water. Changes due to wetting and drying did not change the relative hygroscopicities.

The work of Bouyoucos (*13*) indicated further that the quantity of water which fails to freeze corresponds closely to the wilting coefficient. Lobanov (*14*) found that the amount of unfree soil moisture is about equal to that of the hygroscopic moisture, and that the wilting coefficient of plants varies from 1.5 to 3 times the hygroscopicity of the soil. Thus a more or less direct relation is indicated between the unfree water in soils and their hygroscopic water contents.

Bouyoucos (*13*) also showed that the quantity of unfree water in soils varies from 2 per cent in coarse sand to 80 per cent in fine clay, thus increasing from the simple and noncolloidal types to the complex and colloidal types of soil. Thomas (*12*) showed further that the relative hygroscopic water contents of a widely varying series of soils agreed closely with the ratios of the surfaces of the particles larger than from about 0.1 to 0.2 micron radius.

**Free water.**—Bouyoucos (*8*) and Wintermyer (*10*) found that a portion of the soil water freezes for the first time at about —1.5° C. This portion was designated as free soil water and presumably involves the greater part of the capillary or interstitial water which is held and moves by film forces, and is active from the standpoint of plant requirements.

Shaw (*15*, *16*) drew attention further to the interesting fact that the minimum amount of water retained by absorption and film forces, when excess water is moving downward through a mass of uniform soil, is also readily available to plants but is apparently not able to move under the normal film forces. For medium textured soils this amount of moisture is approximately the same as the moisture equivalent.

Alway (*6*) also found that the maximum amount of water available to plants in ordinary dry-land soils is approximately equal to the difference between the total water content and that represented by the hygroscopic coefficient.

Bouyoucos (*8*) showed that repeated freezing and thawing causes some of the unfree water to become free. Blanck (*17*) found in addition that the hygroscopicity of sandy loam soil is reduced by treatment with caustic lime. On the other hand, Alway, Kline, and McDole (*18*) showed that the amount of hygroscopic moisture in soils tends to increase with a rise in temperature.

Thus it appears that a certain amount of unfree water exists in soils more or less without regard to the total moisture conditions and wholly in addition to the free water. It seems likely that, while the heavier and more complex soils can contain a greater percentage of unfree water than the lighter soils, outside influences, such as weather or chemical or other treatments, may influence the balance between the free and unfree soil water in either soils. The factors involved in the absorption and retention of moisture by soils appear therefore to assume considerable significance in this connection.

### ABSORPTION OF MOISTURE BY SOILS

It appears quite likely that the mechanical composition and physical structure of soils, as well as certain external factors, have a strong influence on their tendencies to absorb moisture.

**Total soil moisture.**—The total surface presented by a soil within certain limits seems to be the main factor in its capacity for moisture absorption. Petit (*19*) established that the size of soil aggregate had no great influence on the absorptive power for moisture when the grains were greater in size than 2 millimeters. However, when the grains were less than 2 millimeters in size the absorptive capacity for moisture increased rapidly with the degree of fineness. Odén (*20*) found that the coarser the clay the less water was absorbed while the stiff, strongly plastic clays absorbed larger quantities of water. Sen and Amin (*21*) found that widely varying soils absorbed quantities of moisture which were exponential functions of their contents of clay. Patten and Gallagher (*2*) found that the absorptive capacity of soil for water vapor is generally higher the finer the texture of the soil and the greater its content of humus. Puri, Crowther, and Keen (*22*) showed that the absolute amounts of water absorbed by a characteristic series of soils at definite high humidities increased with increasing specific surfaces, and were markedly affected by previous treatments known to disintegrate the soil.

Patten and Gallagher (*2*), Sen and Amin (*21*), Puri, Crowther, and Keen (*22*), and Bouyoucos (*23*) all found that the capacity of soils for the absorption of moisture decreases with increasing temperatures, especially above 20° C., and with lower relative humidities.

**Unfree soil moisture.**—Total soil surface seems an especially important factor in the fixation of unfree moisture. Widtsoe and McLaughlin (*1*) at the Utah station found, for example, that the hygroscopicity of soil of uniform physical and chemical composition depended largely upon the content of clay and other colloidal substances. Mendes (*24*) showed that the hygroscopicity of poor soils increased as the contents of organic matter, kaolin, and of such colloids as aluminum and ferric hydrates increased, but not proportionally. Novák (*25*) and Mason (*26*) also established a direct relation between colloid content of soils and moisture content at wilting. Bouyoucos (*27, 28*) established a direct and consistent relationship between unfree water in soils and their heat of wetting.

**Free moisture.**—Bouyoucos (*28*) apparently was unable to establish a relationship between the heat of wetting of soils and the moisture equivalent or between the unfree water and the moisture equivalent. This would suggest that the influence of the colloid content on free water in soils is at least limited. However, Keen (*29*) showed that the colloidal material in soils exercises a profound effect on the moisture relations over a wide range of moisture content, which would indicate that the influence of the colloidal material is therefore not entirely limited to the unfree water.

The evidence thus points to the fact that total soil surface is at least one of the main factors governing the absorptive properties of soils for moisture, and that the surfaces of the colloidal materials present are especially active in the absorption of moisture in the unfree form.

### RETENTION OF MOISTURE BY SOILS

The mechanical composition and physical structure of soils seem to be important factors in moisture retention as well as in absorption. For example, Israelsen and West (*30*) showed that the actual capacity of a given soil for moisture depends upon its texture and structure. Quite naturally sandy or gravelly soils were found to retain the smaller amounts and clay-loam soils the larger amounts. Israelsen (*31*) found further that the percentage of pore space filled with water immediately after irrigation increases with the increase in fineness of the soil texture. These results were also borne out to a greater or lesser extent by Powers (*32*), Juritz (*5*), Leather (*33*), Briggs and McLane (*34*), and

Middleton (*35*). Monroe (*36*) established the fact that the presence of clay in the soil had a much larger unit effect on the water-retaining capacity than did the presence of organic matter, thus in a measure differentiating between the mineral and organic colloids in this respect.

Bradfield (*37*) established a direct relation between specific surface and moisture equivalent of soils. Particles larger than 5 microns in diameter were not appreciably affected by drying or even by ignition. Air drying of particles from 0.025 to 1 micron in diameter, however, resulted in the formation of aggregates which had practically the same moisture equivalent values. Blanck (*38*) found that the capacity of air-dry soils to retain free moisture was less when fertilized than when unfertilized, with the exception of those receiving lime.

The available evidence seems to indicate, therefore, that the manner of existence of moisture in soils, and especially the relative proportions of free and unfree moisture, are governed in some instances and influenced in most by the mechanical composition and physical structure of the soils and by certain external factors, such as temperature, for example. Apparently the most definite indication is that the factors which largely determine manner of existence also influence the absorption and retention of moisture. The exact nature and extent of these influences are yet to be explained, however, and more specific studies, especially of the functions of colloidal materials in this connection, seem desirable, to strengthen efforts at the development of moisture-control measures.

### SOIL-MOISTURE MOVEMENTS

It seems likely that some relations exist between the movements of moisture in soils and its absorption and retention in different forms, which have a bearing on its availability and distribution and which may influence the development of measures for its control. Some knowledge of the manner of and the conditions surrounding soil-moisture movements is available, and, as indicated above, evaporation and capillary movements, as well as movements under the influence of gravity, are important.

**Movements by evaporation.**—Apparently the practical significance of moisture movements in soils by evaporation depends largely upon climatic conditions and the available moisture supply. Veihmeyer and Beckett (*39, p. 104–107*), Bouyoucos (*40*), Leather (*33*), Buckingham and Cameron (*41*), Mohr (*42*), Barker (*43*), and the Rothamsted Experimental Station (*44*) appear to agree substantially that evaporation losses from a soil depend to a large extent upon the presence of water at the soil surface. Their experimental findings suggest that vapor movements from any great depths, resulting in evaporation losses, are not likely to occur. In one instance, in fact, a definite relation was found between the potential evaporating power at the soil surface and the change in the ground-water level.

However, other soil and external factors appear to also influence evaporation. The findings of Harris and Robinson (*45*), Alway, Kline, and McDole (*18*), and Willard and Humbert (*46*) appear to agree that wind velocity and temperature and humidity conditions have considerable of a bearing on the matter. In the first instance air currents greatly increased evaporation up to a certain velocity, and in all instances evaporation was greater the higher the temperature and the lower the humidity.

In addition Harris and Robinson (*45*) showed that evaporation is greater from fine soil particles than from the coarser when both are completely saturated. Willard and Humbert (*46*) showed that the amount of evaporation loss is proportional to the surface exposed. Fisher (*47*) found that the moisture contents of soils at which the vapor pressure of the retained moisture begins to decrease represent some function of the total surface of the soil grains, which in turn depends upon the average size of the grains. Keen (*48*) found further that the rate of evaporation losses from soils at a constant temperature depends upon the amount of clay and organic matter present. The differences due to organic matter were more obvious in soils containing the larger amounts of clay and were small in sandy soils. Evidence was secured that the moisture equivalent of soils measures the percentage of water at which evaporation is first directly affected by the soil particles. These results were confirmed in the main by the findings of Westermann (*49*) and de Angelis d'Ossat (*50*), and by those of von Seelhorst (*51*), and were strengthened somewhat by the findings of Blanck (*17*) that evaporation was most rapid from unlimed soils and was least from soils treated with caustic lime.

Russel and Weakley (*52*) found that evaporation from a free water surface through either dry soil or sand is a linear function of the saturation deficit. The rate of evaporation varies with the porosity of the material, but is not affected by its hygroscopicity. The size rather than the quantity of pore space was found to determine the evaporation loss, and evaporation from a wet mass of soil, when not more moist than the field-carrying capacity, seemed to follow all the laws of vapor movement.

These results suggest rather strongly that evaporation from soils involves primarily the free water therein. Its extent also appears to depend largely upon the physical and other factors in the soil which not only largely govern water retention but permit it to exist in soils in the free state.

**Capillary movement.** — The capillary movement of moisture in soils is a phenomenon which seems more or less closely related with some of the factors determining its availability to crops and influencing its absorption and retention. There appears to be some question as to the practical significance of capillary movement under certain conditions. The California station (*53, p. 47*) found, for example, that in the absence of a free water table the capillary movement of moisture is too slow to be of appreciable benefit in distributing it to growing crops. Shaw and Smith (*54*) showed, however, that the capillary rise to the surface of sandy loam or loam soils is fairly rapid when the water table is 4 feet below the surface. It is slower at 6 feet and comparatively slight at 8 feet, and this appears to be close to the limit of capillary rise in such soils. Thus it appears that the significance of capillary movement may depend largely on the distance of such movement and be, therefore, subject to the same limitations.

It appears also that the water content of a soil has an influence on capillary movement. Widtsoe and McLaughlin (*1*) found that water added up to about 12.75 per cent to a deep soil of uniform physical and chemical composition and holding a maximum amount of water against gravity under field conditions of about 24 per cent and a minimum amount of about 8 per cent was held firmly, but water added above this amount moved readily in obedience to capillary laws.

Alway and Clark (*55*) showed further that when soil having a hygroscopic coefficient of 5.6, a maximum water capacity of 55 per cent, and a content of more than 10 per cent of moisture was placed in contact with the same soil containing only the maximum amount of hygroscopic moisture, there was a practically uniform movement of moisture from all parts of the former to the latter. The greater the water content of the former soil the greater was the capillary movement of water. However, a capillary movement of 30 inches required more than three weeks when approximately 12 per cent of moisture was present. It thus seems likely that the initial amount of moisture present in a soil rather definitely limits both the amount and rate of capillary movement.

Free (*56*) found that the capillary movement of water in soils is controlled and actuated by the forces of surface tension on the water films. Humphreys (*57*) drew attention further to the fact that the surface tension of the soil moisture increases as its temperature decreases, thus accounting for the more rapid capillary movement of moisture toward the surface of soil during the night than during the day. Bouyoucos (*40*) also established this point and showed in addition that the capillary movement of moisture in moist soils is not controlled entirely by the curvature of the capillary films but also by the unsatisfied attractive forces of the soil for water. The percentage of moisture at which the maximum thermal translocation of water occurred was different for different classes of soils, but was about the same for all classes for any one thermal amplitude.

These results seem, therefore, to be related rather logically to the findings of Petit (*19*), Willard and Humbert (*46*), and Tulaikov (*58*) that capillary movement is on the whole greater in rate and in amount in fine-grained than in coarse-grained soils, at least within certain limits.

Keen (*59*) reported the finding that the probable maximum height of capillary rise in soils is almost inversely proportional to the radius of the soil particles if the soil grains are considered as spherical, of one size, and packed in the closest possible manner. However, Petit showed that this condition could be modified somewhat by pulverization, sieving, and sedimentation, resulting in an increase in capillary movement in the coarser-grained soils. Blanck (*17*) also showed that treatment with caustic lime reduced the capillary movement in sandy loam soils almost in proportion to the amount of lime used.

The evidence given thus points to physical structure of soil and certain external factors, such as temperature and mechanical and chemical treatments, as the important factors in the capillary movement of soil moisture. The activity of colloidal phenomena in this connection also seems quite evident. Since moisture distribution in soils and moisture losses in some cases appear to depend in part on capillary movement, a more thorough elucidation of the functions of these factors in this connection seems desirable.

**Gravity movements.** — Movements of moisture downward and laterally in soils by percolation appear to be subject to certain influences in addition to that of gravity. Loughridge (*60*) showed that the unobstructed movement of water is downward in loam soils, with great irregularity in the rate of progress and in the amount of water retained at various depths. Lateral movement appeared to be small in the top soil except where an impervious hardpan was encountered near the surface. Duration of the irrigation period appeared to be a factor in percolation.

Alway and McDole (*61*), Puchner (*62*), and Willard and Humbert (*46*) seem to agree that downward movement of water increases with the sand and gravel contents of the soil and decreases with the clay and humus contents. Alway and McDole showed that loam soils when in capillary contact with a saturated subsoil lost moisture by downward movement until the amount retained bore a close relation to the hygroscopic coefficient. Where the soil column consisted of successive 2-inch layers of loams differing widely in texture, the order of their arrangement exercised no influence on their final water content. However, when a coarse layer of sand or gravel separated the soil column from the subsoil the downward movement of moisture was much delayed. McLaughlin (*63*) found further that heavy and less porous soils showed on the whole a less uniform and less extensive downward moisture movement than that which occurred in the light and more porous soils, although during the first few days the movement was relatively greater in the former. Free (*56*) showed that permeability is governed by the size of the individual interspaces of soil and not by their total amount.

Powers (*64*) found that the resistance offered by the amount, composition, and state of the colloids present in soils is of chief importance in water movements by percolation, and that percolation decreases with increasing fine texture. Botkin (*65*) showed further that the permeability of fine-textured soils is dependent upon the degree of dispersion of the colloids. Bouyoucos (*23*) showed in addition that the rate of water percolation through sandy loam, silt loam, clay loam, and muck soils increased with a rise in temperature up to about 30° and then decreased with further rise in temperature. The rate of percolation through sand increased with a constant rise of temperature, however.

The movements of moisture in soils by evaporation, capillarity, and gravity thus also appear to be governed largely by the physical and mechanical properties of the soils and the colloidal phenomena therein. Just how these factors function is apparently not fully known, but it seems reasonably certain that they deal in this connection primarily with the moisture which is available to crops. A striking indication is that the conditions favoring capillary movement may be somewhat opposed to those favoring percolation. The importance of these movements in soil moisture conservation and regulation needs no argument therefore, and efforts to fully elucidate the factors governing them seem quite desirable.

### SOIL-MOISTURE CONTROL

Some knowledge of a more or less empirical nature is available relating to the influence of certain practices on soil-moisture movements.

**Mulching practices.**—Beckett and Veihmeyer (*36*), Shaw (*16*), Grantham and McCool (*66*), and Young (*67*) seemed to agree that soil mulches have a somewhat limited effect in reducing the losses of water by evaporation from the surface, especially when the initial amount of water present does not exceed the normal water capacity of the soil. Shaw showed in this connection that the soil moisture representing the normal capacity is essentially static, so that no upward movement to supply water for surface evaporation occurs. Thus mulches have little or no effect in conserving soil moisture.

McCall (*68*) found that the soil mulch has an inhibitory effect upon moisture absorption under conditions where individual rains are not of sufficient volume to penetrate the mulch fully. However, the mulch prevents the loss of moisture already in the soil,

and its practical use is therefore considered to depend on climatic conditions which influence the prominence of either the inhibitory effect on absorption or the positive effect on retention, or both.

Harris and Yao (*69*) obtained favorable results with straw mulches and found that the loss of moisture from soil was correlated with the percentage of moisture retained by the mulch. Harris and Turpin (*70*) and Burr (*71*) found a straw mulch to be considerably better than a 2-inch soil mulch. All these investigators and Fortier and Beckett (*72*) found that the effectiveness of mulching increases with its depth, but that there are quite definite practical limitations for the use of this moisture conservation measure for each set of conditions.

Harris and Jones (*73*) found further that the destruction of weeds is more important than mulching for moisture conservation in fallow soils. These investigators and also Krüger (*74*) found that dry mulches composed of fine particles are less effective than when composed of coarser particles, thus suggesting the influence of mechanical composition and physical structure in this connection.

Bouyoucos (*40*) established the further fact that temperature has a very marked influence on the conservation of moisture by mulches. It was found in this connection that the amount of moisture moving from moist and warm soil to cold and dry soil increased with the temperature and the moisture content.

These findings point to the importance of a consideration of both environmental conditions and soil physics in the rational development of mulching practices for soil-moisture control. Temperature appears to be a factor in this connection, but the greatest influence seems to be exerted by the texture, structure, depth, and moisture content of the mulch itself. This suggests that there is considerable yet to be learned about mulching. In fact, Shaw (*75*) and Stewart (*76*) observed that soil moisture losses were appreciably reduced and higher and more uniform temperatures produced by a covering of asphalt-coated paper. This suggests, therefore, that certain principles of soil physics and perhaps of thermodynamics must yet be elaborated before the mulching process is fully developed.

**Cultivation practices.**—Quite a difference of opinion appears to exist among investigators as to the value of cultivation as a moisture conservation measure. The California station (*53*) and Call and Sewell (*77*) found cultivation to be of negligible value in this connection except in so far as it eliminates weeds, whereas Fraps (*78*) found that cultivation increased the water retentive powers and water capacities of a wide series of soils. Fraps and also Fortier and Beckett (*72*) found that cultivation of certain soils decreased evaporation losses. Thomas (*79*) suggested that the initial moisture content of the soil may influence the value of cultivation in conserving moisture.

McCall and Holtz (*80*), Harris and Yao (*69*), Cardon (*81*), and Burns (*82*) appeared to agree that, under dry-farming conditions especially, shallow cultivation is preferable to deep cultivation for moisture conservation. Further work by Mendes de Godoy (*83*) suggested that tilth texture is not so important as tilth structure in moisture conservation.

These results seem to indicate, therefore, that an elucidation of those conditions of tilth structure which favor moisture retention under any conditions is desirable as a basis for the further development of cultivation as a moisture-control measure.

**Permeability.** — The permeability of soils to water is an important factor in the success of moisture-control measures such as drainage and irrigation. The treatment of impermeable soils as a preliminary to such practices therefore assumes considerable importance.

Fraps (*84*) found that cultivation increased percolation through sands and sandy loams, but had little effect upon clays and loams. Treatment with potassium sulphate and manure increased percolation through sandy soils, but decreased it in clay soils.

Blanck (*38*) showed that caustic lime, kainit, superphosphate, ammonium sulphate, and calcium carbonate treatments increased the percolation through sandy loam soil, while sodium nitrate had the opposite effect.

Powers (*64*) found that the greatest increase in percolation through a soil having a high clay content and restricted drainage was produced by treatments with lime and manure, sulphur and manure, green manure, alum, and a saturated solution of calcium sulphate. Botkin (*65*) showed that the flocculation and permeability of soils were improved by additions of aluminum sulphate or of iron sulphate.

The benefit of such treatments on the permeability of soils seems therefore to be due primarily to a change in the colloidal state of the clay content of

such soils. An elucidation of the mechanism of such changes as a basis for the further development of these practices might be advisable.

## CONCLUSION

Measures for the control of soil moisture, including mulching, cultivation, drainage, and irrigation, involve practices the cost of which represents a considerable part of the total cost of crop production. It seems likely, therefore, that unnecessary expenditures of power, labor, and materials may result from their unintelligent use. The above, while not a complete review of all work on the subject, seems to indicate that the knowledge of the mechanism of the existence, movements, and functions of moisture in soils under certain conditions, and of the influence of control and regulation measures thereon, is not sufficient to insure economy. The conclusion of Israelsen (*85*) that applications of hydrodynamics to soil-moisture movements have been rare seems well borne out. His further conclusion that an intimate knowledge of the laws governing the movements of soil moisture is essential to its effective and economical control would appear to be the keynote for further work in the subject.

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Commercial fertilizers. C. H. Jones, G. F. Anderson, and E. F. Boyce. Vt. Sta. Bul. 258, 20 p. 1926.

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Commercial feeding stuffs. H. R. Kraybill, O. S. Roberts, R. O. Bitler, P. B. Curtis, R. F. Hine, and W. C. Aitkinhead. Ind. Sta. Bul. 303, 20 p., illus. 1926.

Commercial feeding stuffs in Kentucky in 1925. J. D. Turner, H. D. Spears, W. G. Terrell, and P. H. Senn. Ky. Sta. Bul. 268, p. 97–137. 1926.

Commercial feeding stuffs, 1925–1926. J. M. Bartlett. Me. Sta. Off. Insp. 120, p. 33–52. 1926.

Inspection of commercial feedstuffs. P. H. Smith and F. J. Kokoski. Mass. Sta. Control Ser. Bul. 36, 29 p. 1926.

Inspection of commercial feeding stuffs, 1926, made for the State Department of Agriculture. T. G. Phillips, T. O. Smith, and A. W. Petre. N. H. Sta. Bul. 224, 51 p. 1926.

Analyses of commercial feeding stuffs and registrations for 1926. C. S. Cathcart. N. J. Stas. Bul. 435, 84 p. 1926.

Inspection of feeds. J. B. Smith and L. J. Hardin. R. I. Sta. Ann. Feed Insp. Circ., 8 p. 1926.

Inspection of feeds. J. B. Smith and R. A. Greene. R. I. Sta. Ann. Feed Insp. Circ., 8 p. 1927.

Commercial feeding stuffs from September 1, 1925, to August 31, 1926. B. Youngblood, F. D. Fuller, and S. D. Pearce. Tex. Sta. Bul. 348, 133 p. 1927.

Commercial feeding stuffs. J. L. Hills, C. H. Jones, C. F. Anderson, and E. F. Boyce. Vt. Sta. Bul. 254, 56 p. 1926.

### REGULATORY PUBLICATIONS, FOODS AND DRUGS

Index to reports on food products and drugs, 1915–1925. E. M. Bailey. Conn. State Sta. Bul. 284, p. 111–155. 1927.

Foods and drugs. J. M. Bartlett. Me. Sta. Off. Insp. 119, 32 p. 1926.

### REGULATORY PUBLICATIONS, SEEDS

The quality of vegetable seed sold in packets in Connecticut. E. M. Stoddard and A. D. McDonnell. Conn. State Sta. Bul. 283, p. 99–110, illus. 1927.

Inspection of agricultural seeds. O. S. Roberts, R. O. Bitler, J. C. Kinsella, E. M. Patt, and A. P. Martin. Ind. Sta. Bul. 302, 68 p., illus. 1926.

Commercial agricultural seeds, 1926. Insecticides and fungicides, 1926. J. M. Bartlett, C. H. White, B. E. Plummer, and L. M. Baker. Me. Sta. Off. Insp. 122, p. 73–88. 1926.

Results of seed tests for 1926 made for the State Department of Agriculture. M. G. Eastman. N. H. Sta. Bul. 226, 18 p. 1926.

Agricultural seed. A. S. Lutman. Vt. Sta. Bul. 259, 14 p. 1926.

### REGULATORY PUBLICATIONS, MISCELLANEOUS

Stallion enrollment.—XV, Report of stallion enrollment work for the year 1926 with lists of stallions and jacks enrolled. Ind. Sta. Circ. 137, 48 p., illus. 1926.

The protein test in marketing wheat. W. O. Whitcomb and E. J. Bell jr. Mont. Sta. Bul. 189, 31 p., illus. 1926.

A chemical investigation of some standard spray mixtures. R. E. Andrew and P. Garman. Conn. State Sta. Bul. 278, p. 491–508. 1926.

Analyses of materials sold as insecticides and fungicides during 1926. C. S. Cathcart and R. L. Willis. N. J. Stas. Bul. 441, 16 p. 1926.

Twelfth annual report of the dairy department creamery license division for the year ending March 31, 1926. W. G. Goss. Ind. Sta. Circ. 136, 24 p., illus. 1926.

Creamery inspection in New Jersey.—Seventh annual report. G. L. Ball. N. J. Stas. Bul. 445, 16 p., illus. 1927.

### PUBLICATION LISTS AND MISCELLANEOUS

Publications available for free distribution. Idaho Sta. Circ. 41, 4 p. 1926.

Abstracts of papers not included in bulletins, finances, meteorology, index. Biographical sketch of Charles Dayton Woods. Me. Sta. Bul. 328, 253–275+XV p., illus. 1925.

Abstracts of Bulletins 328–346 and Circulars 32–42. A. D. Jackson. Tex. Sta. Circ. 44, 18 p. 1927.

Summary of publications. B. C. Pittman. Utah Sta. Circ. 62, 4 p. 1926.

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## INCOME, EXPENDITURES, AND OTHER STATISTICS, 1927

By J. I. Schulte

The following tables give detailed data regarding (1) personnel, publications, and ma ling lists of the experiment stations; (2) revenues and additions to equipment; (3) expenditures from the Hatch, Adams, and Purnell funds; and (4) total disbursements from the United States Treasury under the Hatch, Adams, and Purnell Acts from their passage to the end of the fiscal year, June 30, 1927.

Table 1.—*Personnel, publications, and mailing lists of experiment stations, 1927*

| Station | Persons on staff | Teachers on staff | Persons on staff who assist in extension work | Publications during fiscal year 1926–27 | | Names on mailing list |
|---|---|---|---|---|---|---|
| | *Number* | *Number* | *Number* | *Number* | *Pages* | *Number* |
| Alabama (College) | 32 | 16 | 1 | 4 | 42 | 2,000 |
| Alabama (Tuskegee) | 5 | | | | | |
| Alaska | 7 | | | 1 | 41 | |
| Arizona | 27 | 20 | | 12 | 343 | 4,000 |
| Arkansas | 33 | 23 | | 17 | 323 | 3,000 |
| California | 156 | 90 | 83 | 52 | 1,776 | 3,829 |
| Colorado | 69 | 29 | 14 | 10 | 411 | 850 |
| Connecticut (State) | 33 | | | 16 | 772 | 16,505 |
| Connecticut (Storrs) | 19 | 9 | 2 | 7 | 290 | 11,700 |
| Delaware | 21 | 9 | 3 | 5 | 152 | 6,000 |
| Florida | 54 | 1 | 4 | 15 | 358 | 30,000 |
| Georgia | 15 | 1 | | 19 | 124 | 6,700 |
| Guam | 5 | | | 1 | 20 | |
| Hawaii | 7 | | | 4 | 161 | |
| Idaho | 41 | 18 | 1 | 24 | 390 | 17,500 |
| Illinois | 128 | 76 | 32 | 558 | 2,586 | 23,616 |
| Indiana | 97 | 22 | | 44 | 722 | 36,037 |
| Iowa | 94 | 44 | 1 | 31 | 1,220 | 32,390 |
| Kansas | 96 | 80 | | 13 | 479 | 13,000 |
| Kentucky | 64 | 23 | 4 | 13 | 651 | 12,000 |
| Louisiana | 32 | 5 | 3 | 7 | 292 | 5,901 |
| Maine | 23 | 1 | | 12 | 385 | 20,600 |
| Maryland | 49 | | | 61 | 213 | 25,000 |
| Massachusetts | 64 | 12 | | 26 | 332 | 6,000 |
| Michigan | 100 | 60 | 8 | 26 | 767 | 40,000 |
| Minnesota | 137 | 95 | 3 | 37 | 1,189 | 20,000 |
| Mississippi | 40 | 11 | | 94 | 332 | 20,000 |
| Missouri (College) | 66 | 61 | | 90 | 1,482 | 4,754 |
| Missouri (Fruit) | 1 | | | | | |
| Missouri (Poultry) | 2 | | | | | |
| Montana | 48 | 17 | 7 | 17 | 613 | 6,000 |
| Nebraska | 46 | 22 | | 10 | 263 | 1,430 |
| Nevada | 14 | | | 1 | 30 | 7,000 |
| New Hampshire | 33 | 17 | 17 | 12 | 389 | 7,500 |
| New Jersey (State) | [1] 79 | 42 | 23 | 268 | 1,820 | 18,000 |
| New Jersey (College) | 40 | | | | | |
| New Mexico | 23 | 13 | 5 | 125 | 556 | 10,000 |
| New York (State) | 57 | | | 29 | 687 | 42,000 |
| New York (Cornell) | 93 | 82 | 79 | 18 | 2,032 | 2,774 |
| North Carolina | 44 | 31 | 1 | 5 | 196 | 9,491 |
| North Dakota | 47 | 20 | 3 | 21 | 670 | 9,100 |
| Ohio | 103 | 9 | | 17 | 1,006 | 72,000 |
| Oklahoma | 42 | 34 | | 10 | 125 | 6,000 |
| Oregon | 58 | 35 | | 9 | 186 | 1,740 |
| Pennsylvania | 98 | 77 | | 9 | 272 | 45,770 |
| Pennsylvania (Nutrition) | 9 | | | | | |
| Porto Rico | 8 | | | 2 | 74 | |
| Rhode Island | 14 | 4 | | 15 | 349 | 3,300 |
| South Carolina | 37 | 13 | 8 | 11 | 480 | 6,000 |
| South Dakota | 34 | 31 | 4 | 9 | 367 | 5,000 |
| Tennessee | 31 | 2 | | 27 | 168 | 13,175 |
| Texas | 73 | 5 | | 43 | 964 | 69,402 |
| Utah | 37 | 27 | 5 | 12 | 272 | 7,000 |
| Vermont | 23 | 8 | 1 | 23 | 692 | 4,300 |
| Virginia | 36 | 11 | 2 | 10 | 480 | 12,000 |
| Virgin Islands | 3 | | | 1 | 18 | |
| Washington | 50 | 19 | | 12 | 469 | 14,217 |
| West Virginia | 46 | 28 | 2 | 65 | 468 | 18,500 |
| Wisconsin | 84 | | 67 | 21 | 915 | 55,678 |
| Wyoming | 26 | 12 | 1 | 11 | 262 | 8,750 |
| Total | 2,831 | 1,265 | 384 | 2,012 | 30,676 | 817,509 |

[1] Including 22 also on college station staff not included in total.

TABLE 2.—*Revenues and additions to*

| Station | Federal | | | State | Balances from previous year [1] | Fees | Sales |
|---|---|---|---|---|---|---|---|
| | Hatch fund | Adams fund | Purnell fund | | | | |
| Alabama | $15,000 | $15,000 | $30,000 | $34,500.00 | $7,850.39 | | $14,349.19 |
| Alaska [2] | | | | | | | |
| Arizona | 15,000 | 15,000 | 30,000 | 100,586.01 | 3,046.30 | | 5,903.64 |
| Arkansas | 15,000 | 15,000 | 30,000 | 59,037.48 | | | 21,772.24 |
| California | 15,000 | 15,000 | 30,000 | 516,135.99 | 3,953.04 | $12,070.10 | 93,222.52 |
| Colorado | 15,000 | 15,000 | 30,000 | 118,966.88 | 31,069.06 | | 36,999.91 |
| Connecticut (State) | 7,500 | 7,500 | 14,000 | 209,073.67 | 5,589.53 | 25,500.00 | |
| Connecticut (Storrs) | 7,500 | 7,500 | 16,000 | 32,000.00 | 3,467.39 | | |
| Delaware [3] | 15,000 | 15,000 | 30,000 | 18,500.00 | 3,865.34 | | 15,455.52 |
| Florida [3] | 15,000 | 15,000 | 30,000 | 231,588.33 | 31,036.17 | | 10,001.80 |
| Georgia | 15,000 | 15,000 | 30,000 | 8,000.00 | 7,216.77 | | 9,562.79 |
| Guam [2] | | | | | | | |
| Hawaii [2] | | | | | | | |
| Idaho | 15,000 | 15,000 | 30,000 | 41,499.34 | 2,306.97 | | 3,370.78 |
| Illinois | 15,000 | 15,000 | 30,000 | 414,605.30 | 25,053.42 | | 55,246.78 |
| Indiana | 15,000 | 15,000 | 30,000 | 250,981.95 | 119,391.92 | 133,614.15 | 92,315.21 |
| Iowa [3] | 15,000 | 15,000 | 30,000 | 265,000.00 | 12,494.80 | | 44,356.96 |
| Kansas | 15,000 | 15,000 | 30,000 | 99,690.00 | 19,021.67 | 41,293.26 | 41,675.40 |
| Kentucky | 15,000 | 15,000 | 30,000 | 149,000.00 | 26,433.68 | 90,453.68 | 69,138.65 |
| Louisiana | 15,000 | 15,000 | 30,000 | 65,000.00 | 2,132.79 | 31,498.46 | 15,681.64 |
| Maine | 15,000 | 15,000 | 30,000 | 38,000.00 | 4,632.95 | 10,135.14 | 15,107.95 |
| Maryland | 15,000 | 15,000 | 30,000 | 79,235.45 | 3,006.52 | | 25,610.12 |
| Massachusetts | 15,000 | 15,000 | 30,000 | 149,019.78 | | 48,269.80 | 11,369.29 |
| Michigan | 15,000 | 15,000 | 30,000 | 309,802.00 | | | 31,470.16 |
| Minnesota | 15,000 | 15,000 | 30,000 | 271,922.96 | | 54,267.00 | 127,555.19 |
| Mississippi | 15,000 | 15,000 | 30,000 | 115,540.60 | 16,499.87 | | |
| Missouri | 15,000 | 15,000 | 30,000 | 31,124.91 | 34,135.59 | 28,899.40 | 65,971.91 |
| Montana | 15,000 | 15,000 | 30,000 | 118,824.60 | 4,669.66 | | 36,439.30 |
| Nebraska | 15,000 | 15,000 | 30,000 | 169,199.86 | | | 56,448.37 |
| Nevada | 15,000 | 15,000 | 30,000 | 4,445.50 | | | 4,534.64 |
| New Hampshire | 15,000 | 15,000 | 30,000 | 4,500.00 | 3,284.79 | | 1,546.28 |
| New Jersey (State) | | | | 137,594.14 | | 15,888.34 | 92,890.81 |
| New Jersey (College) | 15,000 | 15,000 | 30,000 | | | | |
| New Mexico | 15,000 | 15,000 | 30,000 | 7,500.00 | 17,458.11 | | 11,500.00 |
| New York (State) | 1,500 | 1,500 | 3,000 | 292,080.00 | 4,526.55 | | 12,239.92 |
| New York (Cornell) | 13,500 | 13,500 | 27,000 | 249,206.64 | | | 26,184.76 |
| North Carolina | 15,000 | 15,000 | 30,000 | 60,000.00 | | | 13,085.06 |
| North Dakota | 15,000 | 15,000 | 30,000 | | 184,866.38 | | 102,220.35 |
| Ohio | 15,000 | 15,000 | 30,000 | 439,685.00 | 253,392.44 | | 61,554.63 |
| Oklahoma | 15,000 | 15,000 | 30,000 | 30,166.10 | 4,794.94 | | 14,386.86 |
| Oregon | 15,000 | 15,000 | 30,000 | 125,000.00 | 40,726.98 | | 52,139.25 |
| Pennsylvania | 15,000 | 15,000 | 30,000 | 64,787.47 | 545.86 | | 2,641.03 |
| Porto Rico [2] | | | | | | | |
| Rhode Island | 15,000 | 15,000 | 30,000 | | | | 4,921.22 |
| South Carolina | 15,000 | 15,000 | 30,000 | 82,432.61 | 2,229.50 | | 57,901.98 |
| South Dakota | 15,000 | 15,000 | 30,000 | 57,920.00 | 12,172.65 | | 23,473.87 |
| Tennessee | 15,000 | 15,000 | 30,000 | 41,111.61 | | | 18,103.89 |
| Texas | 15,000 | 15,000 | 30,000 | 305,826.76 | 42,716.20 | | 103,728.95 |
| Utah | 15,000 | 15,000 | 30,000 | 59,072.05 | | | 19,310.02 |
| Vermont | 15,000 | 15,000 | 30,000 | | | 15,955.00 | 220.09 |
| Virginia | 15,000 | 15,000 | 30,000 | 85,602.78 | 13,226.73 | | 14,100.98 |
| Virgin Islands [2] | | | | | | | |
| Washington | 15,000 | 15,000 | 30,000 | 117,078.67 | 3,770.18 | | 65,045.29 |
| West Virginia | 15,000 | 15,000 | 30,000 | 95,500.00 | | | 54,637.81 |
| Wisconsin | 15,000 | 15,000 | 30,000 | 247,797.94 | | | 67,265.50 |
| Wyoming | 15,000 | 15,000 | 30,000 | 55,294.50 | 22,169.53 | | 4,517.60 |
| Total | 720,000 | 720,000 | 1,440,000 | 6,459,436.88 | 972,754.67 | 507,844.33 | 1,727,176.11 |

[1] Not including balances from Federal funds.
[2] Supported by direct appropriations to the United States Department of Agriculture.
[3] Including balances: Delaware, $704.90, Purnell; Florida, $3,476.26, Purnell; Iowa, $2,034.83, Purnell.

*equipment, experiment stations, 1927*

| Miscellaneous | Total revenue | Additions to equipment | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Buildings | Library | Apparatus | Farm implements | Livestock | Miscellaneous | Total |
| $7,936.33 | $124,635.91 | $5,004.04 | $597.77 | $3,333.59 | $2,299.14 | $22.35 | $1,579.17 | $12,836.06 |
| 76,240.00 | 76,240.00 | | | | | | | |
| | 169,535.95 | 850.00 | 50.00 | 1,000.00 | 3,000.00 | | 1,250.00 | 6,150.00 |
| | 140,809.72 | 6,419.43 | 1,575.03 | 3,911.49 | 4,204.13 | 746.64 | 954.05 | 17,810.77 |
| 20,803.08 | 706,184.73 | 85,698.95 | 5,099.54 | 3,286.01 | 8,347.44 | 2,323.77 | 4,352.75 | 109,108.46 |
| | 247,035.85 | 21,356.00 | 989.00 | 9,121.00 | 7,734.00 | 6,927.00 | | 46,127.00 |
| 12,701.46 | 281,864.66 | 3,337.71 | 1,577.84 | 2,577.79 | 450.00 | | 1,942.20 | 9,885.54 |
| 17,906.53 | 84,373.92 | 804.94 | 497.22 | 754.89 | 227.00 | | 1,104.96 | 3,389.01 |
| | 97,820.86 | | 1,058.42 | 3,300.18 | 1,543.24 | 122.56 | 889.55 | 6,913.95 |
| | 332,626.30 | 42,099.57 | 4,146.95 | 8,083.24 | 6,014.67 | 339.75 | 161.71 | 60,845.89 |
| | 84,779.56 | | 846.44 | 1,337.20 | 690.80 | 864.86 | 537.66 | 4,276.96 |
| 24,160.00 | 24,160.00 | | | | | | | |
| 54,940.00 | 54,940.00 | | | | | | | |
| | 107,177.09 | 923.28 | 65.45 | 2,532.81 | 1,928.43 | 156.22 | 2,339.54 | 7,945.73 |
| | 554,905.50 | 33,430.52 | | | | | 31,273.16 | 64,703.68 |
| 46,889.38 | 703,192.61 | 27,850.95 | 828.51 | 3,546.25 | 4,567.32 | 2,578.45 | 3,744.61 | 43,116.09 |
| | 381,851.76 | 12,000.00 | | 12,350.00 | | 5,400.00 | | 29,750.00 |
| | 261,680.33 | 21,239.93 | 39.42 | 1,044.38 | 8,735.69 | 16,859.56 | 640.99 | 48,559.97 |
| | 395,026.01 | 6,518.62 | 951.10 | 1,149.01 | 2,739.47 | 1,417.00 | 800.72 | 13,575.92 |
| 23,022.36 | 197,335.25 | 6,811.78 | 114.45 | 355.23 | 6,057.61 | 1,476.66 | 129.25 | 14,944.98 |
| | 127,876.04 | 1,591.72 | 1,016.65 | 896.19 | 3,781.70 | | 1,086.06 | 8,372.32 |
| 25,260.80 | 193,112.89 | 724.68 | 484.01 | 1,427.25 | 6,390.70 | 711.29 | 11,325.88 | 21,063.81 |
| 3.00 | 268,661.87 | 16,301.27 | 540.84 | 1,913.18 | 2,518.97 | 163.39 | 3,009.53 | 24,447.18 |
| 1,316.61 | 402,588.77 | 882.29 | 1,695.61 | 2,077.58 | 6,561.49 | 2,133.70 | 1,741.61 | 15,092.28 |
| | 513,745.15 | | 3,614.48 | 17,148.70 | 9,942.87 | 7,406.16 | 2,145.90 | 40,258.11 |
| | 192,040.47 | 21,960.00 | 197.50 | 756.38 | | 579.50 | 2,150.09 | 25,643.47 |
| | 220,131.81 | | 1,500.00 | 1,864.27 | 3,361.62 | 6,329.96 | 821.45 | 13,877.30 |
| | 219,933.56 | 164.61 | 162.96 | 1,425.68 | 617.04 | 147.38 | 891.36 | 3,409.03 |
| | 285,648.23 | 15,225.94 | 401.50 | 5,692.58 | 3,243.92 | 14,104.54 | 9,156.20 | 47,229.68 |
| | 68,980.14 | 386.36 | 15.81 | 1,062.55 | 604.52 | 225.00 | 417.43 | 2,711.67 |
| 22,187.15 | 91,518.22 | 1,438.08 | 637.15 | 1,383.71 | 3,037.99 | 19.78 | 1,587.78 | 8,104.49 |
| 137.12 | 246,510.41 | 27,319.35 | 1,464.09 | 19,330.99 | 1,234.68 | 10,791.50 | 9,450.59 | 69,591.20 |
| | 60,000.00 | | | | | | | |
| | 96,458.11 | 1,845.84 | 25.50 | 1,026.13 | 2,557.69 | 1,719.00 | | 7,174.16 |
| 94.09 | 314,940.56 | | 2,573.72 | 7,790.28 | 5,767.59 | 37.88 | 7,829.12 | 23,998.59 |
| | 329,391.40 | 5,440.19 | 1,943.99 | 2,468.26 | 3,275.46 | 75.00 | 3,815.40 | 17,018.30 |
| 4,651.94 | 137,737.00 | 19,153.93 | 669.09 | 4,299.11 | 4,320.51 | 6,311.87 | | 34,754.51 |
| 8,000.00 | 355,086.73 | | 619.00 | 2,716.00 | 4,578.00 | 2,350.00 | 2,500.00 | 12,763.00 |
| 5,042.31 | 819,674.38 | 62,345.04 | 598.81 | 1,555.76 | 11,688.75 | 7,963.69 | 5,968.82 | 90,120.87 |
| | 109,347.90 | 1,684.77 | 502.06 | 756.44 | 6,391.16 | 2,919.05 | 1,125.35 | 13,378.83 |
| | 277,866.23 | 6,680.79 | 64.54 | 2,288.48 | 6,654.38 | 6,577.86 | | 22,266.05 |
| 16,249.38 | 144,223.74 | | 170.57 | 2,541.46 | 581.85 | 801.26 | 1,200.03 | 5,295.17 |
| 56,460.00 | 56,460.00 | | | | | | | |
| | 64,921.22 | 386.00 | 460.00 | 90.00 | 625.00 | 200.00 | 478.00 | 2,239.00 |
| | 202,564.09 | 32,612.00 | | 2,804.37 | 8,541.37 | 2,210.50 | 24,720.88 | 70,889.12 |
| | 153,566.52 | | 676.76 | 3,722.05 | 2,238.57 | 4,708.39 | | 11,345.77 |
| 3,666.67 | 122,882.17 | 7,169.83 | 1,097.00 | 1,488.39 | 1,957.47 | 60.00 | 615.29 | 12,387.98 |
| 61,444.54 | 573,716.45 | 28,437.38 | 1,100.32 | 9,293.17 | 15,560.45 | 6,196.71 | 6,372.43 | 66,960.46 |
| | 138,382.07 | 600.00 | 300.00 | 2,087.00 | 3,405.00 | 1,000.00 | 500.00 | 7,892.00 |
| | 76,175.09 | 3,236.39 | 232.88 | 1,527.50 | 557.83 | 12.00 | | 5,566.60 |
| 1,027.85 | 173,958.34 | 3,515.14 | 1,094.60 | 110.00 | 1,575.00 | | 1,360.00 | 7,654.74 |
| 22,180.00 | 22,180.00 | | | | | | | |
| | 245,894.14 | 2,131.89 | 1,729.93 | 1,623.60 | 3,226.64 | 517.00 | 1,646.53 | 10,875.59 |
| | 210,137.81 | 9,288.09 | 273.90 | 211.17 | 2,281.09 | 5,000.00 | | 17,054.25 |
| 42,214.73 | 417,278.17 | 5,378.51 | 1,531.95 | 4,617.30 | 6,458.87 | 2,423.56 | 2,417.39 | 22,827.58 |
| | 141,981.63 | 21,219.35 | 900.00 | 1,231.91 | 3,040.00 | 5,398.94 | | 31,790.20 |
| 554,535.33 | 13,101,747.32 | 571,465.16 | 46,732.36 | 166,310.51 | 195,122.12 | 138,329.73 | 156,033.44 | 1,273,993.32 |

TABLE 3.—*Expenditures from United States appropriations under the*

| Station | Amount of appropriation | Classified expenditures | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Salaries | Labor | Publications | Postage and stationery | Freight and express | Heat, light, and water | Chemical supplies |
| Alabama | $15,000 | $9,892.34 | $2,283.57 | $25.73 | $599.39 | $54.27 | $29.15 | $53.64 |
| Arizona | 15,000 | 14,990.65 | | | 9.35 | | | |
| Arkansas | 15,000 | 7,750.00 | 1,957.72 | 2,557.99 | 104.29 | 79.94 | 63.80 | 301.28 |
| California | 15,000 | 15,000.00 | | | | | | |
| Colorado | 15,000 | 14,844.59 | 30.38 | | 56.43 | | | 2.26 |
| Connecticut (State) | 7,500 | 7,500.00 | | | | | | |
| Connecticut (Storrs) | 7,500 | 7,500.00 | | | | | | |
| Delaware | 15,000 | 10,140.00 | 1,010.66 | 1,241.12 | 928.65 | 49.63 | 75.79 | 95.09 |
| Florida | 15,000 | 15,000.00 | | | | | | |
| Georgia | 15,000 | 8,176.08 | 2,179.98 | 542.49 | 745.36 | 198.06 | 972.71 | 70.99 |
| Idaho | 15,000 | 11,496.23 | 1,823.62 | | 10.93 | | 1.25 | 199.77 |
| Illinois | 15,000 | 15,000.00 | | | | | | |
| Indiana | 15,000 | 15,000.00 | | | | | | |
| Iowa | 15,000 | 8,415.00 | 566.72 | 996.97 | 262.56 | .10 | 99.14 | 90.17 |
| Kansas | 15,000 | 9,700.00 | 3,677.73 | | 25.20 | 44.20 | | 29.57 |
| Kentucky | 15,000 | 14,821.32 | | 30.44 | | | | |
| Louisiana | 15,000 | 8,791.63 | 3,500.42 | 1,189.06 | 262.49 | 30.66 | 160.86 | |
| Maine | 15,000 | 8,157.99 | 3,638.93 | 11.59 | 218.38 | 63.55 | 768.40 | 19.02 |
| Maryland | 15,000 | 14,375.39 | 535.00 | | 2.34 | | 31.08 | 8.71 |
| Massachusetts | 15,000 | 14,861.43 | 80.00 | | | | | |
| Michigan | 15,000 | 15,000.00 | | | | | | |
| Minnesota | 15,000 | 15,000.00 | | | | | | |
| Mississippi | 15,000 | 8,274.81 | 2,449.27 | 168.00 | 238.26 | 166.01 | 272.14 | |
| Missouri | 15,000 | 7,362.83 | 2,400.08 | 15.29 | 116.47 | 444.03 | 84.95 | 116.65 |
| Montana | 15,000 | 14,696.40 | 12.17 | | 25.25 | 25.52 | | 63.03 |
| Nebraska | 15,000 | 15,000.00 | | | | | | |
| Nevada | 15,000 | 9,413.70 | 2,538.95 | 18.35 | 606.20 | 8.75 | 36.45 | 14.31 |
| New Hampshire | 15,000 | 10,163.05 | 507.84 | 1,068.02 | 613.23 | 323.83 | 700.00 | 3.00 |
| New Jersey | 15,000 | 10,100.05 | 1,104.13 | | 290.72 | 107.87 | 140.23 | 256.10 |
| New Mexico | 15,000 | 8,044.96 | 2,824.82 | 1,364.23 | 191.34 | 115.28 | 255.05 | 249.63 |
| New York (Cornell) | 13,500 | 6,884.33 | 4,789.84 | | 77.43 | 50.76 | | 620.35 |
| New York (State) | 1,500 | 1,500.00 | | | | | | |
| North Carolina | 15,000 | 13,454.66 | 126.19 | | 315.37 | 6.08 | 5.00 | 102.37 |
| North Dakota | 15,000 | 15,000.00 | | | | | | |
| Ohio | 15,000 | 5,560.00 | 211.01 | 305.76 | 747.96 | 349.84 | 4,504.10 | 256.34 |
| Oklahoma | 15,000 | 6,673.34 | 3,027.66 | 698.67 | 124.10 | 403.23 | 76.20 | 469.15 |
| Oregon | 15,000 | 8,373.32 | 4,159.39 | | 109.22 | 143.79 | | 150.83 |
| Pennsylvania | 15,000 | 12,000.00 | 918.52 | 1,795.20 | | 21.25 | | 1.50 |
| Rhode Island | 15,000 | 9,436.08 | 2,480.96 | 645.91 | 237.14 | 115.36 | 67.50 | 2.37 |
| South Carolina | 15,000 | 7,550.70 | 2,207.34 | 468.10 | 863.45 | 66.55 | 161.55 | 154.02 |
| South Dakota | 15,000 | 7,396.59 | 4,012.62 | 2,062.80 | 71.31 | 17.29 | 17.50 | 295.45 |
| Tennessee | 15,000 | 8,156.00 | 3,196.68 | 1,199.73 | 360.51 | 50.01 | 1,034.94 | 12.21 |
| Texas | 15,000 | 12,584.96 | 1,000.00 | | 260.03 | | | |
| Utah | 15,000 | 11,315.16 | 1,531.18 | | 27.85 | 18.73 | 37.90 | 23.88 |
| Vermont | 15,000 | 7,045.17 | 2,391.17 | 1,416.99 | 566.69 | 42.92 | 867.39 | 170.22 |
| Virginia | 15,000 | 9,025.00 | 3,078.42 | 53.00 | 434.32 | 124.30 | 99.39 | 235.35 |
| Washington | 15,000 | 10,078.24 | 1,642.62 | 2,006.50 | 46.06 | | | 119.96 |
| West Virginia | 15,000 | 8,916.69 | 1,760.56 | 69.66 | 7.35 | | 25.00 | 205.08 |
| Wisconsin | 15,000 | 11,012.74 | 976.69 | 663.29 | | | 4.40 | 1,268.02 |
| Wyoming | 15,000 | 10,110.66 | 4,889.34 | | | | | |
| Total | 720,000 | 526,542.09 | 75,522.18 | 20,614.89 | 9,555.63 | 3,121.81 | 10,591.87 | 5,660.32 |

*act of March 2, 1887 (Hatch Act) for the year ended June 30, 1927*

| Classified expenditures | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Seeds, plants, and sundry supplies | Fertilizers | Feeding stuffs | Library | Tools, implements, and machinery | Furniture and fixtures | Scientific apparatus | Livestock | Traveling expenses | Contingent expenses | Buildings and land |
| $181.72 | $488.63 | $303.04 | $398.79 | $103.79 | $401.62 | $50.40 | ---- | $133.92 | ---- | ---- |
| 481.39 | 3.00 | 847.79 | 126.61 | 119.83 | 40.00 | 98.47 | $310.80 | 157.09 | ---- | ---- |
| 10.50 | ---- | 6.75 | ---- | ---- | 12.00 | 24.77 | ---- | 12.32 | ---- | ---- |
| 132.63 | 140.27 | ---- | 529.22 | 38.25 | 164.13 | 1.35 | ---- | 270.06 | $28.70 | $154.45 |
| 322.41 | 150.00 | 1.00 | 607.71 | 495.03 | 55.03 | 36.78 | 113.85 | 207.88 | 9.00 | 115.64 |
| 244.68 | 6.00 | 752.55 | ---- | 38.83 | ---- | 5.58 | ---- | 420.56 | ---- | ---- |
| 678.48 | 224.60 | 3,498.21 | ---- | 5.80 | ---- | 53.81 | ---- | 108.44 | ---- | ---- |
| 233.69 | ---- | ---- | 17.30 | 314.66 | 28.25 | 136.97 | ---- | 285.18 | ---- | 507.25 |
| | | | | | | | | 148.24 | | |
| 166.44 | 46.00 | 66.52 | ---- | 282.84 | 29.65 | ---- | ---- | 135.79 | ---- | 337.64 |
| 118.86 | ---- | 1,026.10 | 465.23 | 31.76 | 2.89 | 12.85 | ---- | 424.94 | ---- | 39.51 |
| 31.37 | ---- | ---- | 7.50 | 3.41 | 5.20 | ---- | ---- | ---- | ---- | ---- |
| | | | | | | | | 58.57 | | |
| 856.25 | 300.00 | 998.90 | 29.00 | 691.23 | 34.45 | ---- | ---- | 225.39 | 78.48 | 217.81 |
| 610.63 | ---- | 2,841.67 | 466.50 | 238.92 | 68.28 | 21.76 | 26.25 | 161.24 | ---- | 24.45 |
| 2.46 | 26.78 | ---- | 75.13 | 1.50 | ---- | 35.83 | ---- | 35.93 | ---- | ---- |
| 201.15 | ---- | 420.59 | 9.87 | 81.86 | 1,047.75 | 5.32 | ---- | 596.75 | ---- | ---- |
| 444.85 | 91.83 | ---- | 368.63 | 203.20 | 136.54 | 56.50 | ---- | 319.48 | ---- | ---- |
| 211.12 | 12.73 | 360.00 | 168.51 | 198.98 | 43.21 | 25.30 | ---- | 1,305.60 | 32.26 | 643.19 |
| 300.00 | 335.18 | 83.33 | ---- | 531.54 | 25.03 | 162.45 | 83.00 | 339.16 | ---- | 95.00 |
| 328.39 | 280.31 | ---- | ---- | 81.25 | 88.55 | 47.00 | ---- | 237.21 | 1.00 | 13.58 |
| 5.01 | ---- | ---- | ---- | ---- | ---- | 285.99 | ---- | 699.33 | ---- | ---- |
| 74.91 | 3.00 | 2,466.00 | ---- | ---- | 338.00 | 183.08 | ---- | ---- | ---- | ---- |
| 681.14 | 80.67 | 647.25 | ---- | 871.96 | 93.39 | 301.43 | 362.65 | 489.16 | ---- | ---- |
| 580.34 | 54.60 | 76.72 | ---- | 98.51 | ---- | 6.50 | ---- | 1,083.61 | 1.30 | 161.87 |
| 217.29 | 7.50 | ---- | ---- | 1.66 | ---- | ---- | ---- | 37.08 | ---- | ---- |
| 378.59 | 559.17 | 214.78 | 208.66 | 166.29 | 12.10 | 1.75 | 200.00 | 155.41 | 21.50 | 96.43 |
| 774.49 | 613.64 | 657.55 | 550.94 | 590.62 | 78.90 | ---- | ---- | 129.06 | 133.09 | ---- |
| 76.89 | ---- | 106.00 | ---- | 148.38 | 66.00 | 398.89 | ---- | 238.01 | ---- | 92.27 |
| 114.30 | 41.70 | ---- | 339.47 | 38.24 | 28.44 | 10.20 | ---- | 261.20 | 2.68 | 153.69 |
| 165.20 | ---- | ---- | ---- | ---- | ---- | 45.00 | 794.81 | ---- | ---- | 150.00 |
| 177.09 | ---- | 1,026.97 | ---- | 14.50 | 105.00 | 3.30 | 15.00 | 692.14 | ---- | 11.30 |
| 341.23 | 50.00 | 3.00 | 160.00 | 698.41 | 139.41 | 301.50 | 12.00 | 278.56 | 51.50 | 463.84 |
| 536.31 | 305.08 | ---- | 295.69 | 205.36 | 112.57 | 124.39 | ---- | 311.31 | ---- | 59.51 |
| 141.55 | 82.17 | ---- | ---- | 39.04 | 4.90 | 86.50 | ---- | 752.46 | ---- | ---- |
| 936.77 | 646.38 | 12.00 | ---- | 472.48 | ---- | 457.95 | ---- | 1,425.39 | ---- | 64.69 |
| 135.20 | ---- | ---- | ---- | 158.98 | 69.55 | 519.60 | ---- | 191.53 | ---- | ---- |
| 10,893.33 | 4,549.24 | 16,416.72 | 4,824.76 | 6,967.11 | 3,230.84 | 3,501.22 | 1,918.36 | 12,328.00 | 359.51 | 3,402.12 |

TABLE 4.—*Expenditures from United States appropriations received under*

| Station | Amount of appropriation | Classified expenditures | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Salaries | Labor | Postage and stationery | Freight and express | Heat, light, and water | Chemical supplies | Seeds, plants, and sundry supplies |
| Alabama | $15,000 | $11,250.00 | $474.25 | $26.44 | $268.30 | $304.59 | $541.50 | $369.10 |
| Arizona | 15,000 | 11,141.60 | 1,462.83 | 23.01 | 123.71 | | 417.97 | 130.76 |
| Arkansas | 15,000 | 8,925.00 | 2,626.29 | 25.10 | 113.50 | 5.00 | 1,316.23 | 254.37 |
| California | 15,000 | 15,000.00 | | | | | | |
| Colorado | 15,000 | 15,000.00 | | | | | | |
| Connecticut (State) | 7,500 | 7,500.00 | | | | | | |
| Connecticut (Storrs) | 7,500 | 7,500.00 | | | | | | |
| Delaware | 15,000 | 11,540.00 | 613.63 | 45.10 | 35.23 | | 1,351.35 | 131.02 |
| Florida | 15,000 | 15,000.00 | | | | | | |
| Georgia | 15,000 | 9,909.14 | 1,161.32 | 109.38 | 235.47 | 725.36 | 452.31 | 291.60 |
| Idaho | 15,000 | 12,334.31 | 1,678.66 | 8.10 | | | 619.48 | 100.40 |
| Illinois | 15,000 | 9,654.88 | 5,304.27 | | | | | |
| Indiana | 15,000 | 12,885.00 | 257.13 | 26.99 | 9.58 | 1.96 | 371.48 | 307.66 |
| Iowa | 15,000 | 9,070.93 | 3,823.85 | 38.21 | | 44.06 | 924.82 | 316.66 |
| Kansas | 15,000 | 10,300.00 | 3,184.40 | 4.91 | | | 537.94 | 83.27 |
| Kentucky | 15,000 | 14,764.45 | 235.55 | | | | | |
| Louisiana | 15,000 | 12,152.45 | 952.40 | 47.75 | 3.64 | | 208.94 | 123.29 |
| Maine | 15,000 | 14,782.42 | 11.21 | 1.12 | 18.81 | | 35.07 | |
| Maryland | 15,000 | 13,647.50 | | 8.63 | | 72.71 | 347.17 | 46.43 |
| Massachusetts | 15,000 | 15,000.00 | | | | | | |
| Michigan | 15,000 | 15,000.00 | | | | | | |
| Minnesota | 15,000 | 15,000.00 | | | | | | |
| Mississippi | 15,000 | 9,308.24 | 3,184.58 | 21.35 | 59.56 | 227.92 | 119.61 | 164.91 |
| Missouri | 15,000 | 4,252.55 | 3,977.10 | 124.34 | 219.31 | 159.05 | 1,019.39 | 437.09 |
| Montana | 15,000 | 11,511.27 | 2,040.92 | 14.23 | 5.48 | | 414.80 | 189.85 |
| Nebraska | 15,000 | 15,000.00 | | | | | | |
| Nevada | 15,000 | 10,433.10 | 2,943.03 | .24 | 3.77 | | 120.78 | 29.60 |
| New Hampshire | 15,000 | 12,142.44 | 1,085.60 | 27.19 | 74.58 | .49 | 203.36 | 149.27 |
| New Jersey | 15,000 | 12,910.03 | 244.09 | 25.67 | 32.60 | 254.20 | 815.73 | 159.39 |
| New Mexico | 15,000 | 9,445.76 | 2,958.96 | 66.59 | 178.32 | 438.00 | 455.37 | 249.13 |
| New York (State) | 1,500 | 1,500.00 | | | | | | |
| New York (Cornell) | 13,500 | 12,786.80 | 593.60 | | | | 29.03 | 75.00 |
| North Carolina | 15,000 | 13,020.00 | 340.58 | | 68.44 | 34.63 | 308.53 | 357.59 |
| North Dakota | 15,000 | 15,000.00 | | | | | | |
| Ohio | 15,000 | 10,800.00 | 1,897.97 | 74.46 | | | 338.69 | 59.10 |
| Oklahoma | 15,000 | 11,019.29 | 1,082.99 | 3.40 | 62.45 | | 522.91 | 418.17 |
| Oregon | 15,000 | 11,528.33 | 469.66 | 13.90 | 104.07 | 39.80 | 1,032.14 | 582.19 |
| Pennsylvania | 15,000 | 13,550.95 | 922.15 | | 8.32 | | 51.15 | 30.40 |
| Rhode Island | 15,000 | 7,968.57 | 2,096.87 | 46.39 | 54.43 | 153.34 | 241.18 | 70.18 |
| South Carolina | 15,000 | 11,411.60 | 1,704.66 | 83.44 | 20.95 | 200.00 | 145.43 | 176.03 |
| South Dakota | 15,000 | 6,758.29 | 5,320.56 | .54 | 42.06 | | 208.18 | 260.18 |
| Tennessee | 15,000 | 13,235.00 | 451.05 | 2.70 | 153.22 | 215.90 | 296.50 | 32.02 |
| Texas | 15,000 | 13,125.00 | 897.67 | .03 | 44.94 | 38.34 | 545.31 | 58.55 |
| Utah | 15,000 | 11,025.00 | 2,303.02 | 4.85 | 117.63 | | 488.82 | 166.34 |
| Vermont | 15,000 | 11,526.08 | 2,634.33 | 35.32 | 22.64 | 25.42 | 117.65 | 77.48 |
| Virginia | 15,000 | 14,656.65 | 103.97 | | | | | |
| Washington | 15,000 | 12,383.18 | 1,582.94 | 37.79 | 2.00 | | 403.03 | 64.51 |
| West Virginia | 15,000 | 11,581.63 | 423.71 | 67.25 | | | 461.85 | 352.52 |
| Wisconsin | 15,000 | 10,675.00 | 3,496.44 | 8.30 | | | 241.89 | 84.21 |
| Wyoming | 15,000 | 14,280.98 | 719.02 | | | | | |
| Total | 720,000 | 580,193.42 | 65,261.26 | 1,022.72 | 2,083.01 | 2,940.77 | 15,705.59 | 6,398.27 |

*the act of March 16, 1906 (Adams Act) for the year ended June 30, 1927*

| Classified expenditures | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fertilizers | Feeding stuffs | Library | Tools, implements, and machinery | Furniture and fixtures | Scientific apparatus | Livestock | Traveling expenses | Contingent expenses | Buildings and land | Balance |
| $16.25 | $842.12 | $5.50 | $126.32 | $71.55 | $646.76 | | $57.36 | | | |
| | | 4.50 | 86.94 | | 527.87 | | 772.50 | $288.20 | $20.11 | |
| | 256.55 | 197.83 | 597.95 | 57.32 | 294.30 | $79.97 | 250.59 | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| 46.50 | | 10.49 | 37.10 | | 1,019.09 | | 170.49 | | | |
| 16.00 | 719.84 | 68.83 | 35.56 | | 716.06 | 285.00 | 260.93 | | $13.20 | |
| | 47.50 | | 1.82 | | 34.50 | | 175.23 | | | |
| | | | | | | | 40.85 | | | |
| | 57.87 | | 9.35 | | 534.83 | 528.45 | 9.70 | | | |
| | 684.96 | 21.00 | 19.90 | | 26.38 | 15.00 | 14.23 | | | |
| | 523.91 | | 145.09 | 8.98 | 21.03 | 63.25 | 123.82 | 3.40 | | |
| | 38.43 | 56.52 | 22.00 | | 204.70 | | 801.29 | | 388.59 | |
| | | | | | 1.50 | | 149.87 | | | |
| | | | 28.81 | 775.40 | 73.35 | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| 19.73 | | 87.03 | 827.22 | 149.22 | 657.00 | | 166.25 | | 7.38 | |
| | 2,560.01 | 10.35 | 438.97 | 160.82 | 1,088.61 | 195.50 | 45.00 | 2.40 | 309.51 | |
| | 19.30 | | 9.23 | 13.60 | 98.03 | 105.27 | 573.41 | | 4.61 | |
| | 832.50 | | 8.00 | | 7.93 | 249.80 | 371.25 | | | |
| | 226.12 | | 404.86 | 50.48 | 133.32 | | 124.56 | | 377.73 | |
| 10.00 | | 1.60 | 58.73 | 28.50 | 190.41 | | 132.06 | 25.20 | 111.79 | |
| 173.38 | 235.87 | 11.50 | 351.44 | 31.90 | | 220.60 | 48.94 | | 134.24 | |
| 5.51 | | | | | 10.06 | | | | | |
| | | | | | 398.50 | | 471.73 | | | |
| | | | | | | | | | | |
| | 88.80 | | 25.00 | 69.50 | 135.38 | 1,384.30 | | | 126.80 | |
| | 622.93 | | 517.29 | | 461.08 | 75.00 | 113.64 | | 100.85 | |
| 14.70 | 26.14 | 12.15 | 173.10 | 108.50 | 350.10 | | 43.22 | 2.00 | | |
| | | 149.05 | | | 287.98 | | | | | |
| | 757.27 | 149.72 | 310.40 | 3.00 | 26.88 | | 58.27 | 5.00 | 114.50 | $2,944.00 |
| | | | 246.29 | | 249.92 | | 61.68 | | 700.00 | |
| 35.68 | | 530.53 | 50.28 | 182.08 | 1,528.18 | | 83.44 | | | |
| | | 32.55 | 35.21 | 26.46 | 157.00 | | 156.70 | 9.75 | 195.94 | |
| | 138.56 | | | | 85.50 | 50.00 | | 16.10 | | |
| | | 5.00 | 112.08 | | 232.66 | | 481.46 | | 63.14 | |
| 33.25 | | 24.03 | 68.84 | 209.70 | 57.60 | | 79.76 | | 87.90 | |
| | 228.58 | | 9.05 | | | | | | 1.75 | |
| 6.52 | | 10.50 | 22.15 | 1.75 | 258.96 | | 226.67 | | | |
| 108.50 | 312.10 | | 47.34 | | 1,402.51 | | 225.53 | | 17.06 | |
| | 192.90 | | 4.55 | | 291.71 | 5.00 | | | | |
| | | | | | | | | | | |
| 486.02 | 9,412.26 | 1,388,68 | 4,830.87 | 1,948.76 | 12,709.69 | 3,257.14 | 6,290.43 | 352.05 | 2,775.10 | 2,944.00 |

TABLE 5.—*Expenditures from United States appropriations received under*

| Station | Amount of appropriation | Classified expenditures | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Salaries | Labor | Publications | Postage and stationery | Freight and express | Heat, light, and water | Chemical supplies |
| Alabama | $30,000 | $16,202.95 | $4,157.15 | | $501.75 | $340.05 | $353.98 | $1,237.31 |
| Arizona | 30,000 | 16,250.79 | 3,418.44 | $659.69 | 26.72 | 266.37 | 52.98 | 940.14 |
| Arkansas | 30,000 | 20,625.16 | 715.71 | 1,958.92 | 557.40 | 56.06 | 204.22 | 399.64 |
| California | 30,000 | 28,152.05 | 1,847.95 | | | | | |
| Colorado | 30,000 | 24,799.64 | 532.66 | | 281.37 | 66.56 | 25.18 | 352.68 |
| Connecticut (State) | 14,000 | 8,042.37 | 2,996.77 | | 102.82 | .39 | | 258.91 |
| Connecticut (Storrs) | 16,000 | 5,570.00 | 6,937.79 | | 253.72 | 2.17 | | |
| Delaware | [1] 30,000 | 18,912.46 | 937.63 | 496.72 | 63.80 | 94.32 | 20.98 | 817.71 |
| Florida | [2] 30,000 | 17,404.17 | 1,056.68 | | 999.95 | 18.19 | 115.42 | 2,280.23 |
| Georgia | 30,000 | 19,334.00 | 3,090.86 | | 110.29 | 326.90 | 720.23 | 558.10 |
| Idaho | 30,000 | 17,330.29 | 2,090.48 | 2,561.87 | 148.09 | 261.38 | 43.52 | 358.77 |
| Illinois | 30,000 | 19,129.81 | 2,832.87 | 436.78 | 436.27 | 95.12 | | 324.30 |
| Indiana | 30,000 | 19,700.87 | 4,153.17 | 991.31 | 497.12 | 4.70 | .90 | 63.77 |
| Iowa | [3] 30,000 | 13,719.93 | 4,962.18 | 14.00 | 141.58 | 27.82 | 54.80 | 205.32 |
| Kansas | 30,000 | 15,000.00 | 10,503.28 | | 15.57 | | 57.43 | 567.52 |
| Kentucky | 30,000 | 25,342.20 | 1,186.72 | 355.29 | 55.19 | 44.27 | | 674.40 |
| Louisiana | 30,000 | 15,418.33 | 4,662.36 | 959.50 | 184.97 | 447.58 | 17.19 | 177.92 |
| Maine | 30,000 | 24,860.06 | | 587.42 | 174.29 | 48.58 | | 87.83 |
| Maryland | 30,000 | 22,014.99 | 1,492.89 | 14.00 | 117.44 | 83.64 | | 73.84 |
| Massachusetts | 30,000 | 22,266.03 | 1,119.19 | 989.18 | 288.35 | 11.23 | 1.22 | 544.22 |
| Michigan | 30,000 | 18,881.08 | 5,828.71 | 164.33 | 437.03 | 15.08 | | 948.65 |
| Minnesota | 30,000 | 22,813.31 | 1,700.00 | 344.11 | 320.51 | 34.49 | | 622.97 |
| Mississippi | 30,000 | 17,535.02 | 5,734.70 | 3.95 | 114.04 | 365.63 | 142.13 | 4.38 |
| Missouri | 30,000 | 13,225.96 | 6,187.70 | 389.52 | 726.07 | 178.69 | 167.27 | 548.30 |
| Montana | 30,000 | 18,999.46 | 4,139.37 | | 141.22 | 53.29 | 1.45 | 323.85 |
| Nebraska | 30,000 | 20,207.84 | 2,566.31 | 315.80 | 266.92 | 59.81 | 2.94 | 339.42 |
| Nevada | 30,000 | 16,634.92 | 3,924.26 | | 219.96 | 37.83 | 312.55 | 124.49 |
| New Hampshire | 30,000 | 19,817.00 | 2,031.29 | 537.26 | 206.62 | 37.59 | | 563.23 |
| New Jersey | 30,000 | 23,280.03 | 943.63 | | 66.69 | 4.78 | 837.44 | 616.82 |
| New Mexico | 30,000 | 12,217.35 | 4,906.15 | 969.74 | 152.68 | 231.37 | 38.15 | 18.45 |
| New York (Cornell) | 27,000 | 20,115.15 | 178.75 | 13.00 | 30.85 | 3.42 | | 406.79 |
| New York (State) | 3,000 | 1,800.00 | 1,200.00 | | | | | |
| North Carolina | 30,000 | 16,653.23 | 2,774.12 | | 213.77 | 47.33 | | 320.58 |
| North Dakota | 30,000 | 24,305.76 | 613.95 | | 133.28 | .15 | | .90 |
| Ohio | 30,000 | 23,505.50 | 1,709.42 | | 57.19 | | | 405.12 |
| Oklahoma | 30,000 | 18,502.96 | 5,196.82 | 25.75 | 242.26 | 40.08 | 13.00 | 681.21 |
| Oregon | 30,000 | 18,607.42 | 3,835.11 | 54.59 | 232.57 | 203.97 | 18.16 | 431.76 |
| Pennsylvania | 30,000 | 20,736.05 | 3,474.43 | 300.00 | 78.93 | 56.27 | 74.05 | 773.62 |
| Rhode Island | 30,000 | 20,758.53 | 3,428.43 | 983.11 | 100.11 | 180.67 | 766.01 | 124.69 |
| South Carolina | 30,000 | 20,224.35 | 3,032.04 | 915.11 | 597.76 | 246.63 | | 202.11 |
| South Dakota | 30,000 | 19,158.17 | 3,186.88 | 1,752.83 | 258.09 | 62.91 | | 605.09 |
| Tennessee | 30,000 | 22,805.52 | 1,661.85 | 3.30 | 25.04 | 171.87 | 91.48 | 642.86 |
| Texas | 30,000 | 13,685.00 | 5,335.18 | 4.50 | 668.62 | 188.80 | | 828.04 |
| Utah | 30,000 | 20,821.76 | 3,235.61 | 60.00 | 151.96 | 172.50 | | 208.97 |
| Vermont | 30,000 | 16,807.28 | 5,160.82 | 1,424.53 | 438.49 | 44.30 | 714.50 | 497.16 |
| Virginia | 30,000 | 16,118.91 | 2,349.90 | 4,648.23 | 427.20 | 32.95 | 1.60 | |
| Washington | 30,000 | 20,442.88 | 2,824.28 | 1,247.01 | 225.37 | 79.71 | | 118.51 |
| West Virginia | 30,000 | 19,663.03 | 4,031.48 | | 37.64 | 99.19 | | 66.24 |
| Wisconsin | 30,000 | 18,519.06 | 5,982.46 | 1.60 | 177.78 | 2.83 | | 511.03 |
| Wyoming | 30,000 | 18,161.49 | 4,668.76 | 560.64 | 76.02 | 21.38 | | 47.72 |
| Total | 1,440,000 | 925,080.12 | 160,537.19 | 24,743.59 | 11,781.36 | 4,868.85 | 4,848.78 | 20,905.57 |

[1] Including balance from previous year, $704.90.
[2] Including balance from previous year, $3,476.26.
[3] Including balance from previous year, $2,034.83.

*the act of February 24, 1925 (Purnell Act), for the year ended June 30, 1927*

| Classified expenditures | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Seeds, plants, and sundry supplies | Fertilizers | Feeding stuffs | Library | Tools, implements, and machinery | Furniture and fixtures | Scientific apparatus | Livestock | Traveling expenses | Contingent expenses | Buildings and land |
| $801.57 | $199.93 | $569.88 | $158.85 | $1,199.59 | $550.57 | $1,662.75 | $22.35 | $1,111.82 | | $929.50 |
| 1,340.78 | 339.95 | | | 108.80 | 7.50 | 454.78 | | 2,925.06 | $208.00 | 3,000.00 |
| 190.16 | | 130.45 | 302.13 | 192.43 | 1,240.66 | 688.08 | | 2,738.98 | | |
| 111.64 | 24.00 | | 113.20 | 5.00 | 399.59 | 750.94 | 1.00 | 2,334.44 | 170.00 | 32.10 |
| 80.32 | | | 15.75 | 553.24 | 59.26 | 238.17 | | 1,608.05 | 43.95 | |
| 132.75 | | | 28.80 | | 617.37 | | | 2,457.40 | | |
| 711.13 | 237.94 | 1,295.68 | 251.03 | 914.57 | 504.67 | 2,146.09 | 122.56 | 2,128.97 | | 343.74 |
| 323.17 | | 121.49 | 137.11 | 61.71 | 3,593.84 | 1,767.37 | | 1,742.86 | | 377.81 |
| 458.99 | 60.00 | 1,899.62 | 168.90 | 630.05 | 482.63 | 584.36 | 466.01 | 1,035.04 | | 74.02 |
| 280.43 | 115.20 | | 24.09 | 217.81 | 454.10 | 630.23 | | 5,483.74 | | |
| 185.72 | | 5.48 | 8.00 | 388.51 | 952.16 | 996.73 | 82.25 | 4,047.72 | 20.17 | 58.11 |
| 82.92 | | | 1.00 | | 319.37 | 7.84 | | 4,169.03 | 8.00 | |
| 1,252.07 | | 3,120.05 | | 55.54 | 1,200.98 | 955.95 | 6.00 | 2,454.80 | 15.00 | 1,813.98 |
| 166.55 | | 155.09 | | 136.28 | 110.25 | 376.44 | 2,042.15 | 526.78 | | 342.66 |
| 115.65 | | 6.75 | 123.24 | | 249.80 | 172.38 | | 1,674.11 | | |
| 785.35 | 146.30 | 623.52 | | 1,421.55 | | | 559.51 | 2,034.65 | | 2,561.27 |
| 42.58 | | | | 1,086.06 | 262.67 | 231.84 | | 1,819.64 | 787.03 | 12.00 |
| 449.50 | 16.49 | | 69.58 | 63.09 | 873.32 | 670.24 | 283.00 | 2,898.30 | 5.00 | 874.68 |
| 79.45 | | 27.68 | 28.97 | 40.88 | 1,380.58 | 561.15 | 163.39 | 2,262.81 | 8.00 | 227.67 |
| 107.94 | | 170.27 | 103.95 | 1.00 | 527.81 | 510.62 | | 2,293.53 | 10.00 | |
| 192.16 | | 24.00 | | 32.82 | 610.15 | 1,269.45 | 7.00 | 1,721.55 | | 307.48 |
| 281.31 | 401.20 | 492.00 | 14.49 | 284.32 | 508.13 | 54.65 | 2,385.15 | 1,519.52 | 16.00 | 143.38 |
| 1,296.30 | 118.50 | 3,185.18 | 6.00 | 978.61 | 262.91 | 826.59 | 260.75 | 1,303.51 | .60 | 337.54 |
| 168.01 | | 245.66 | 87.83 | 606.31 | 877.76 | 1,271.82 | 42.11 | 2,881.86 | | 160.00 |
| 154.73 | | 2,980.36 | 2.20 | 317.96 | 489.92 | 794.34 | 435.10 | 1,066.35 | | |
| 722.85 | 94.75 | 2,361.28 | | 708.28 | 1,112.31 | 115.80 | 275.00 | 2,844.84 | | 510.88 |
| 183.53 | 290.10 | 110.43 | 19.22 | 910.81 | 1,159.62 | 849.56 | 19.78 | 2,035.29 | 1.00 | 1,227.67 |
| 98.07 | | 607.92 | 139.89 | 187.82 | 675.16 | 177.46 | 30.00 | 1,737.07 | 6.70 | 590.52 |
| 2,057.41 | 34.07 | 1,252.56 | 3.00 | 1,396.31 | 390.90 | 404.82 | 2,350.25 | 2,219.89 | 18.30 | 1,338.60 |
| 281.86 | | 508.99 | 10.78 | 375.52 | 1,596.98 | 477.45 | | 1,683.46 | 1,317.00 | |
| 691.61 | | 5,496.99 | | | | 245.25 | 2,101.51 | 1,455.61 | | |
| 129.87 | | 933.00 | 3.75 | | 121.80 | 55.01 | | 3,702.53 | | |
| 233.06 | | 1,824.38 | 12.80 | 160.37 | 400.00 | 365.46 | 180.10 | 1,146.60 | | |
| 454.31 | | 1,311.66 | 2.55 | 652.24 | 492.06 | 459.80 | 783.65 | 1,075.85 | 3.00 | 62.80 |
| 496.14 | .50 | 67.80 | | 572.74 | 236.22 | 330.65 | 63.00 | 4,429.02 | 420.35 | |
| 173.25 | | 11.76 | | 83.47 | 2.27 | 742.62 | 229.20 | 3,180.04 | | 84.04 |
| 176.32 | 523.04 | 1,803.46 | 75.95 | 77.21 | 476.05 | 52.13 | | 276.66 | 22.50 | 175.13 |
| 155.53 | | | 9.00 | 37.61 | 149.21 | 198.37 | | 4,187.66 | | 44.62 |
| 301.66 | | 706.88 | 35.41 | 577.13 | 799.49 | 597.52 | 85.00 | 1,872.94 | | |
| 308.58 | | | 113.16 | 608.71 | 666.29 | 1,371.24 | | 858.81 | 1.91 | 669.38 |
| 232.76 | | 350.34 | 45.40 | 78.64 | 1,929.35 | 2,567.00 | 87.50 | 1,069.01 | | 2,929.86 |
| 288.48 | | 12.36 | 16.36 | 349.60 | 138.32 | 449.72 | 160.00 | 2,974.77 | | 959.59 |
| 104.90 | | 397.11 | 22.70 | 150.13 | 452.21 | 427.85 | | 2,423.78 | 141.15 | 793.09 |
| .30 | | | 84.60 | 640.84 | 429.61 | 15.94 | | 4,824.78 | | 425.14 |
| 1,103.30 | 74.59 | | 19.07 | 675.36 | 255.59 | 244.63 | | 2,689.70 | | |
| 303.02 | | 3,259.49 | 34.38 | 137.05 | 74.70 | 305.14 | 15.00 | 1,973.64 | | |
| 662.63 | | 306.21 | 4.40 | 246.87 | 341.16 | 1,205.93 | 107.46 | 1,896.40 | | 34.18 |
| 262.20 | | 391.52 | | 540.96 | | 28.24 | 1,526.25 | 3,699.34 | 15.48 | |
| 19,212.82 | 2,676.56 | 36,767.30 | 2,297.54 | 18,463.80 | 28,435.30 | 29,310.40 | 14,892.03 | 110,498.21 | 3,239.14 | 21,441.44 |

TABLE 6.—*Disbursements from the United States Treasury to the States and Territories for agricultural experiment stations under the acts of Congress approved March 2, 1887, March 16, 1906, and February 24, 1925*

| State or Territory | Hatch Act | | Adams Act | | Purnell Act | |
|---|---|---|---|---|---|---|
| | 1888–1926 | 1927 | 1906–1926 | 1927 | 1926 | 1927 |
| Alabama | $438,956.42 | $15,000 | $281,619.89 | $15,000 | $20,000 | $30,000.00 |
| Arizona | 549,803.10 | 15,000 | 284,955.61 | 15,000 | 20,000 | 30,000.00 |
| Arkansas | 583,139.12 | 15,000 | 284,900.00 | 15,000 | 20,000 | 30,000.00 |
| California | 585,000.00 | 15,000 | 284,926.84 | 15,000 | 20,000 | 30,000.00 |
| Colorado | 584,718.82 | 15,000 | 283,638.93 | 15,000 | 20,000 | 30,000.00 |
| Connecticut | 585,000.06 | 15,000 | 285,000.00 | 15,000 | 20,000 | 30,000.00 |
| Dakota Territory | 56,250.00 | | | | | |
| Delaware | 583,382.87 | 15,000 | 280,475.12 | 15,000 | 20,000 | 29,295.10 |
| Florida | 584,966.04 | 15,000 | 284,996.06 | 15,000 | 20,000 | 26,523.74 |
| Georgia | 580,593.43 | 15,000 | 272,092.87 | 15,000 | 20,000 | 30,000.00 |
| Idaho | 509,324.13 | 15,000 | 280,842.22 | 15,000 | 20,000 | 30,000.00 |
| Illinois | 584,564.95 | 15,000 | 284,851.62 | 15,000 | 20,000 | 30,000.00 |
| Indiana | 584,901.19 | 15,000 | 285,000.00 | 15,000 | 20,000 | 30,000.00 |
| Iowa | 585,000.00 | 15,000 | 285,000.00 | 15,000 | 20,000 | 27,965.17 |
| Kansas | 584,995.00 | 15,000 | 285,000.00 | 15,000 | 20,000 | 30,000.00 |
| Kentucky | 584,996.57 | 15,000 | 285,000.00 | 15,000 | 20,000 | 30,000.00 |
| Louisiana | 585,000.00 | 15,000 | 285,000.00 | 15,000 | 20,000 | 30,000.00 |
| Maine | 584,999.62 | 15,000 | 285,000.00 | 15,000 | 20,000 | 30,000.00 |
| Maryland | 584,967.40 | 15,000 | 284,236.48 | 15,000 | 20,000 | 30,000.00 |
| Massachusetts | 584,617.70 | 15,000 | 285,000.00 | 15,000 | 20,000 | 30,000.00 |
| Michigan | 584,676.10 | 15,000 | 281,341.20 | 15,000 | 20,000 | 30,000.00 |
| Minnesota | 584,917.78 | 15,000 | 284,345.00 | 15,000 | 20,000 | 30,000.00 |
| Mississippi | 585,000.00 | 15,000 | 285,000.00 | 15,000 | 20,000 | 30,000.00 |
| Missouri | 580,097.24 | 15,000 | 284,999.90 | 15,000 | 20,000 | 30,000.00 |
| Montana | 495,000.00 | 15,000 | 282,417.04 | 15,000 | 20,000 | 30,000.00 |
| Nebraska | 584,932.16 | 15,000 | 285,000.00 | 15,000 | 20,000 | 30,000.00 |
| Nevada | 584,214.32 | 15,000 | 283,180.28 | 15,000 | 20,000 | 30,000.00 |
| New Hampshire | 585,000.00 | 15,000 | 285,000.00 | 15,000 | 20,000 | 30,000.00 |
| New Jersey | 584,949.97 | 15,000 | 284,392.06 | 15,000 | 20,000 | 30,000.00 |
| New Mexico | 549,509.05 | 15,000 | 285,000.00 | 15,000 | 20,000 | 30,000.00 |
| New York | 584,757.18 | 15,000 | 284,463.01 | 15,000 | 20,000 | 30,000.00 |
| North Carolina | 585,000.00 | 15,000 | 270,000.00 | 15,000 | 20,000 | 30,000.00 |
| North Dakota | 526,502.26 | 15,000 | 284,638.85 | 15,000 | 20,000 | 30,000.00 |
| Ohio | 585,000.00 | 15,000 | 283,514.02 | 15,000 | 20,000 | 30,000.00 |
| Oklahoma | 509,002.16 | 15,000 | 264,535.19 | 15,000 | 20,000 | 30,000.00 |
| Oregon | 570,156.64 | 15,000 | 280,000.00 | 15,000 | 20,000 | 30,000.00 |
| Pennsylvania | 584,967.43 | 15,000 | 284,995.41 | 15,000 | 20,000 | 30,000.00 |
| Rhode Island | 585,000.00 | 15,000 | 282,464.20 | 15,000 | 20,000 | 30,000.00 |
| South Carolina | 584,542.15 | 15,000 | 283,460.12 | 15,000 | 20,000 | 30,000.00 |
| South Dakota | 528,250.00 | 15,000 | 280,000.00 | 15,000 | 20,000 | 30,000.00 |
| Tennessee | 585,000.00 | 15,000 | 285,000.00 | 15,000 | 20,000 | 30,000.00 |
| Texas | 585,000.00 | 15,000 | 282,592.26 | 15,000 | 20,000 | 30,000.00 |
| Utah | 450,000.00 | 15,000 | 284,821.94 | 15,000 | 20,000 | 30,000.00 |
| Vermont | 585,000.00 | 15,000 | 285,000.00 | 15,000 | 20,000 | 30,000.00 |
| Virginia | 582,824.12 | 15,000 | 284,949.01 | 15,000 | 20,000 | 30,000.00 |
| Washington | 522,102.65 | 15,000 | 281,080.11 | 15,000 | 20,000 | 30,000.00 |
| West Virginia | 584,968.71 | 15,000 | 282,859.12 | 15,000 | 20,000 | 30,000.00 |
| Wisconsin | 585,000.00 | 15,000 | 285,000.00 | 15,000 | 20,000 | 30,000.00 |
| Wyoming | 570,000.00 | 15,000 | 285,000.00 | 15,000 | 20,000 | 30,000.00 |
| Total | 27,461,546.28 | 720,000 | 13,582,584.36 | 720,000 | 960,000 | 1,433,784.01 |

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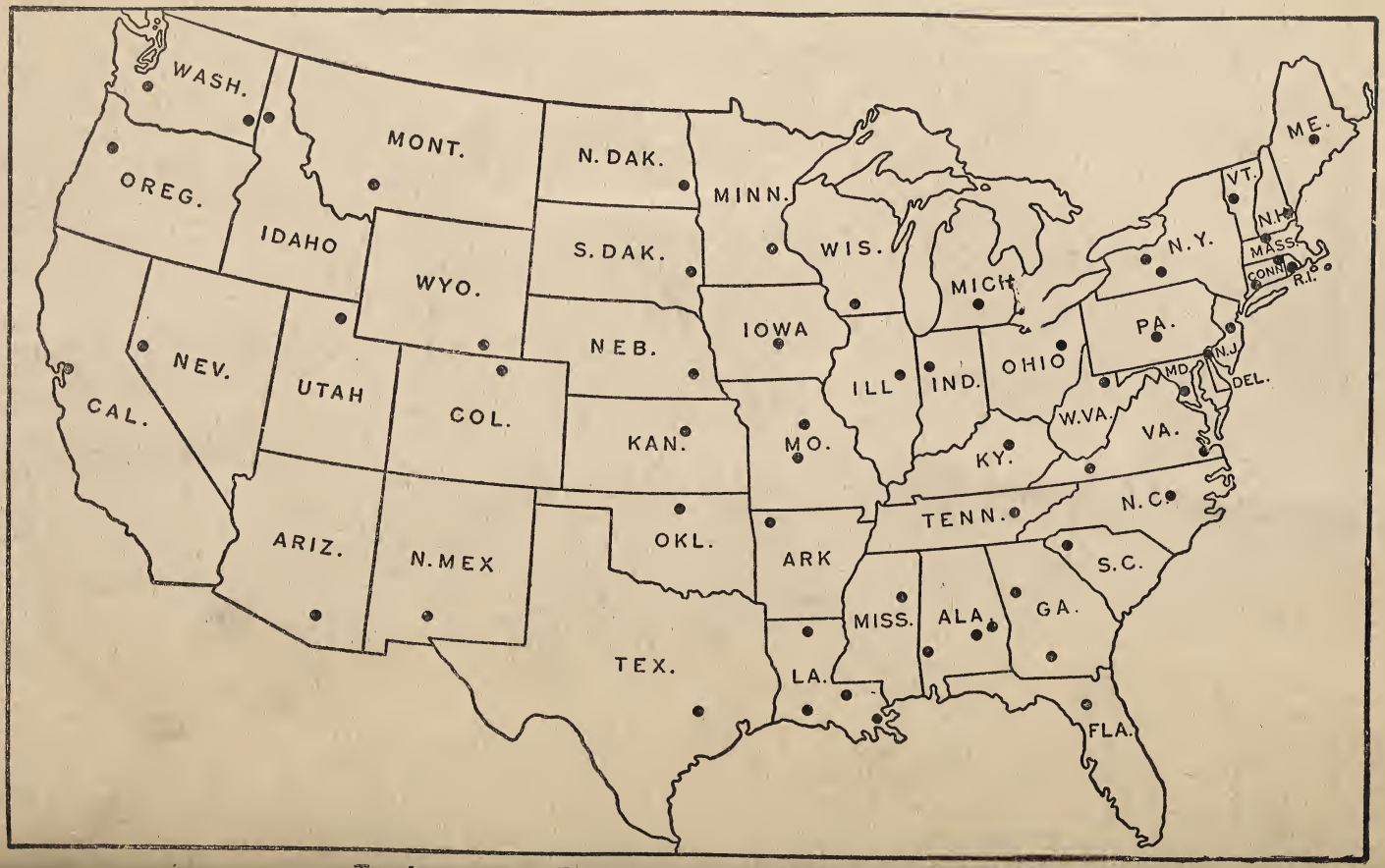


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